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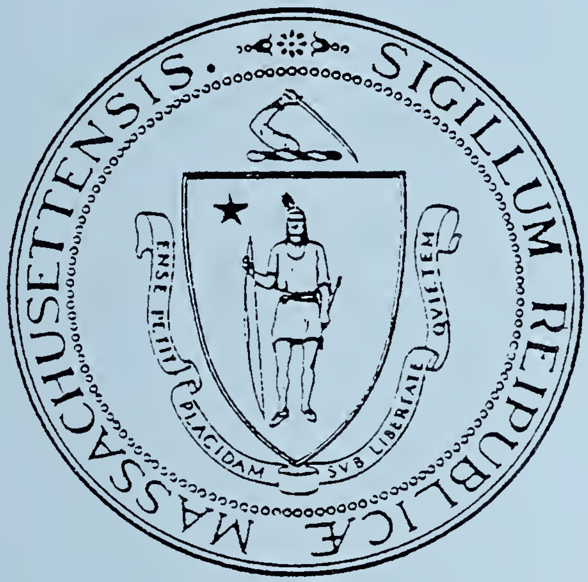
ENGINEERING EDUCATION

Current Trends and Future Directions

June 1984



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ENGINEERING EDUCATION IN MASSACHUSETTS

CURRENT TRENDS AND FUTURE DIRECTIONS

Dr. Joseph C. Hogan
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Engineering Review
Executive Summary

In their review of engineering programs, the team of outside evaluators chaired by Dr. Joseph Hogan, identified problems in Massachusetts which are, in many respects, similar to problems found nationwide. Recent significant increases in undergraduate enrollments have resulted in overcrowded classrooms and laboratories. The increased enrollments and simultaneous advances in technology have, in turn, contributed to the problem of inadequate and outmoded facilities and equipment.

On the graduate level, several factors have contributed to an overall decline in enrollment. Since baccalaureate engineers can demand high salaries, fewer choose to pursue graduate work. The increase in undergraduate enrollments has placed demands on faculty to teach undergraduate classes, leaving them with less time to carry on research and to advise graduate students. The negative effects of declining graduate enrollment are heightened because an increase in the representation of foreign nationals among graduate engineering students means that a larger percentage of our graduate engineers will not be working in this country.

In Massachusetts, engineering education is especially important because the state must have a steady flow of engineering graduates to meet the present and future needs of industry, to attract new industries to the state and to keep Massachusetts competitive when compared to other states. Educational planning which considers the delicate balance between supply and demand for engineers will be very important. Recognizing this need the Board of Regents recently received a report from its Ad Hoc Committee on Engineering Manpower. This Committee concluded that no methodology now exists for satisfactorily predicting the balance between supply and demand. The Committee recommended that a monitoring system be put in place to track data on supply and demand for engineers.

At the present time, it appears that there is an excess supply of chemical and civil engineers. Some division of opinion exists as to whether or not the supply of mechanical engineers has kept up with the demand. Opinions differ widely as to whether the number of electrical engineering graduates projected will meet the demand. Future program planning will need to monitor changes such as the demographic shifts associated with the decline of traditional college age students, future technological breakthroughs and the development of subspecialties in engineering and then determine if such changes merit adjustments in the number and type of engineering programs approved in Massachusetts.

The review team recommended action concerning allocation of resources, course development at all stages of professional training, and collaboration among the various entities that influence engineering education.

The specific recommendations are as follows:

1. The Board of Regents should take steps to influence the quality of pre-professional academic training, including strengthening science and mathematics instruction at the secondary school level.

Community Colleges

2. All community colleges should offer two years of mathematics beginning with calculus, one year of chemistry taught with laboratory, and one year of physics (based on calculus) taught with laboratory.

3. Those community colleges with fairly large engineering transfer programs should offer some engineering courses if it is possible to do so given their currently available resources.

4. Those community colleges with large numbers of engineering transfer students and with suitable resources should offer the eingineering courses normally required in the first two years of an engineering program.

5. Individual program reviews completed by the community colleges emphasize the special needs of each program. Those colleges with engineering transfer programs, particularly Northern Essex and Springfield Technical Community College, should be encouraged to include specific requests for the transfer programs in their FY'86 budget submissions.

6. Roxbury Community College

The Board of Regents should support the upgrading of mathematics and science and the institution's goal toward offering courses applicable to the first two years of engineering.

The College should offer two full years of mathematics, beginning with calculus, one year of chemistry taught with laboratory, and one year of physics (based on calculus) taught with laboratory,

Funds should be provided to adequately staff the above and for adequate laboratories associated with the science courses.

State Colleges

7. It is recommended that all state colleges develop strong mathematics and science programs.

Fitchburg, Salem and Westfield State Colleges

8. The Board of Regents should continue to encourage the improvement of mathematics and science at the colleges, but approval should not be given for the initiation of engineering programs.

State Universities

9. A special fund of $10,500,000 should be set up to be administered by the Board of Regents for the immediate purchase of equipment in the university engineering schools.

10. An equipment fund should be set up for the continuing updating of laboratory equipment. A minimum amount of $2,500,000 per year is needed.

11. An immediate allocation of $3,000,000 is needed for renovation of sub-standard space and a facilities study should be initiated to determine long-range needs for new buildings.

12. Enhancement of faculty salaries is needed to be competitive with other engineering schools and industry. It is estimated that a minimum of $500,000 is needed for this correction.

13. The universities should work with the unions to permit more flexibility, so that performance can be properly rewarded.

14. Provisions should be made for adding professional technical staff and secretarial help, as universities are woefully understaffed at the present time.

15. Computing facilities and equipment should be upgraded and better access provided for faculty and students.

16. Library allocations should be increased to overcome present inadequacies.

17. Maintenance funds should be increased to properly take care of equipment.

University of Lowell

18. Approval should be given to initiate the Doctor of Engineering program in Electrical and Mechanical Egineering.

Southeastern Massachusetts University

19. Authorization for the Ph.D. degree should be delayed until the Master of Science in Electrical Engineering degree is truly viable and more mature.

University of Massachusetts/Boston

20. The Board of Regents should continue to support the Engineering Collaborative Program, monitoring it for its long-term effect.

21. The University of Massachusetts/Boston should be permitted to initiate a Bachelor of Science in Engineering Physics program once it has provided additional evidence of both the demand by industry for its graduates and the interest of the students in the program. This program is not intended to move U.Mass./Boston in the direction of baccalaureate engineering.

Independent Institutions

22. The independent institutions should keep the Board of Regents informed as to their long-range planning.

23. Independent universities should work more closely with other engineering schools where such cooperation is for the common good.

Non-Institutional

24. There should be established a committee of the leaders of the engineering schools and representative industries to explore and seek possible solutions to high quality graduate engineering education for employed engineers.

25. Because of the great needs in engineering education, the state should do everything possible to facilitate gifts by private industry.

The Ad Hoc Committee on Engineering Manpower recommends that:

A monitoring system be put in place to track data in the Commonwealth on supply and demand for engineers.

ACKNOWLEDGMENT

This is to acknowledge the efforts of the many people who contributed to this study. The universities and colleges provided the Board of Regents information and statistics about their programs. On our visits to the campuses, all of the institutions were well organized and very hospitable. Thanks are also due to Dr. W. Edward Lear, Dr. Richard Ungrodt and Dr. Robert Page for their visits to the public institutions. Particular thanks to Dr. Claire Van Ummersen, Associate Vice Chancellor for Academic Affairs for her dedicated efforts in all facets of the Study. The Board of Regents are to be commended for initiation of studies such as this. It has been a privilege for me to participate in this effort.

Dr. Joseph C. Hogan
Dean Emeritus
University of Notre Dame

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I. INTRODUCTION

The Board of Regents of Higher Education of the Commonwealth of Massachusetts was authorized by the Legislature in 1980, and became operational in March of 1981. The Board was directed to analyze the present and future goals, the needs and requirements of public higher education in the Commonwealth; to establish overall goals to achieve a well-coordinated and quality system of public higher education in the Commonwealth; and to prepare a five year master plan.

As part of its statewide academic planning function, the Regents recognized that such planning must set long-range policy objectives and program priorities for all of higher education. The Board of Regents has the responsibility to determine the higher education needs of the state, both in terms of manpower for the state's economic development and in terms of its individual citizens and also to decide how resources can best be utilized to meet these needs. State government and business must also take an active role in planning by adequately projecting long-range manpower requirements. Such statewide planning focuses on program need, program capacity and program quality and adaptability.

In order to plan effectively to meet these objectives, the Regents directed that a number of statewide reviews or studies of selected academic fields or program areas be undertaken periodically when some statewide planning issue is identified. Engineering was one of the two areas chosen by the Board for initial review. There were a number of reasons for selecting engineering. They include:

- The problems of maintaining quality programming in the face of rapidly changing technology; and increasing enrollments without a corresponding increase in resources;
- The dependence of the high technology industries of Massachusetts on the engineering schools within the state; and
- The needs of the state in providing a steady flow of engineering graduates to meet the present needs of industry, to attract new industry to the state, and to keep Massachusetts industries in a competitive posture with respect to similar industries in other states.

Furthermore, prior to this study, requests had been made to the Board of Regents for new undergraduate and graduate programs as well as expansion of existing programs. Special needs were cited for the Boston area. Problems concerning obsolescence of equipment became increasingly evident. As a high cost program, it became imperative that engineering be studied.

The purpose of this review is to provide an evaluation of the present status of engineering education in the Commonwealth of Massachusetts, to comment on the future plans of the various institutions, and finally, to make recommendations that will provide guidance to the state for the future health of engineering education.

CHAPTER I

STATUS OF ENGINEERING EDUCATION

1.1 National Overview

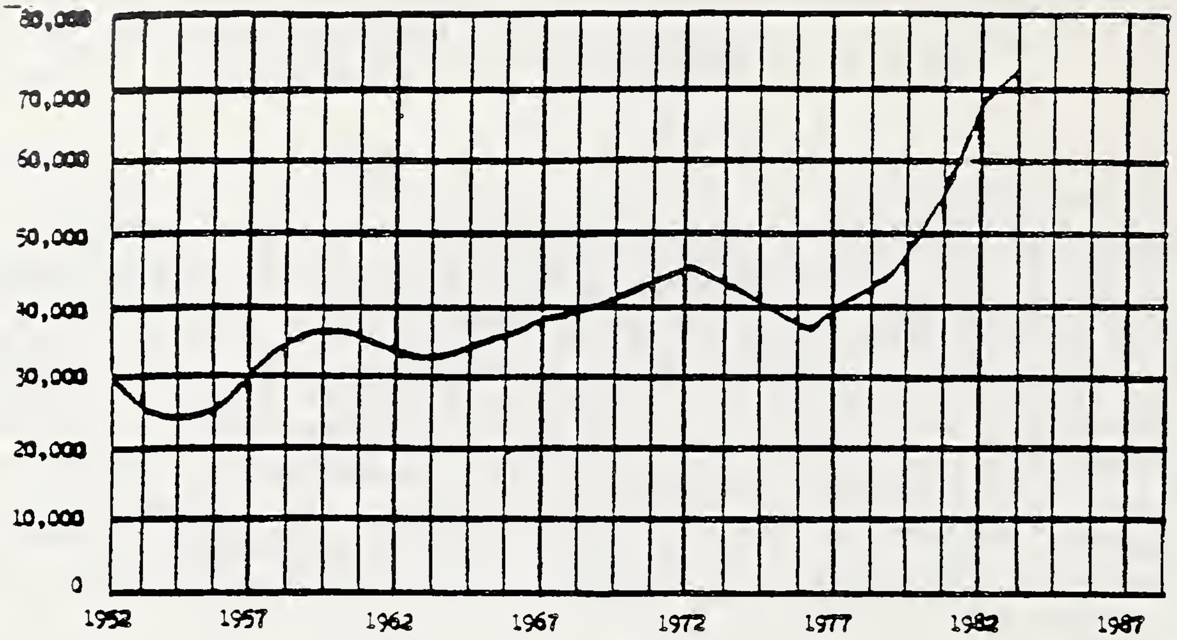
Engineering Education has been the subject of many studies and surveys during the past several years. It is generally agreed that a true crisis exists at the national level at this time. The factors contributing to this condition include burgeoning undergraduate enrollments, shortage of faculty, leveling of graduate enrollments, outmoded and inadequate facilities and equipment, underrepresentation of women and minorities, and an increasing percentage of foreign national graduate students. These factors will all be separately discussed in the sections that follow.

1.1.1 Engineering Undergraduate Enrollments and Degrees

The number of degrees awarded is the most effective measure of the output of engineering educational institutions. Enrollments however are important indicators of the load on faculty and facilities. Freshman enrollments are particularly indicative of trends and are useful in predicting future numbers of graduates at the bachelor's level.

The number of B.S. degrees awarded in engineering has fluctuated widely since World War II. The post-war veterans bulge pushed degrees awarded to 48,160 in 1950, but the number dropped to 22,236 in 1954. The next peak was 38,134 degrees in 1959 with a relatively minor drop to 33,458 in 1963. A gradual increase in the number of degrees occurred and the next peak of 44,190 occurred in 1972. Due initially to the publicity of the aerospace industry lay-offs and shortly thereafter to the economic recession of the early 1970's, enrollments dropped and in 1976 only 37,970 degrees were awarded. In spite of the recession, by the mid-1970's graduates were still highly sought after by industry. enrollments skyrocketed and 72,471 degrees were awarded in 1983. These fluctuations took place during a period of rapidly increasing population of the college age group. Figure 1-1 shows degree variations since 1952.

Figure 1-1
Undergraduate Engineering Degrees Earned
1952-1983



Total full-time undergraduate enrollments have also shown wide variations. In 1969 a total of 234,530 undergraduates were enrolled in engineering, but this figure dropped to 186,705 in Fall of 1973, and more than doubled to 469,393 in Fall 1983. Total enrollments include all undergraduate students and hence, some of the fluctuations are somewhat smoothed out due to the four plus years a student is in the program. Freshman enrollments are therefore more sensitive to the rapidly changing nature of the interest in engineering as a career. Freshman enrollments went from 74,113 in 1969 to 51,925 in 1973 and more than doubled to 115,303 in 1982. Engineering undergraduate enrollments since 1972 are given in Table 1-1.

Table 1-1
UNDERGRADUATE ENGINEERING ENROLLMENTS 1972-1982

Engineering Student	Fall 1972	Fall 1974	Fall 1976	Fall 1978	Fall 1980	Fall 1982
Freshman Year, FT	52,100	63,444	82,250	95,805	110,149	115,303
Sophomore Year, FT	55,891	70,326	63,003	75,150	84,982	89,915
Junior Year, FT	45,874	43,007	56,835	69,816	80,024	90,682
Senior Year, FT	49,895	44,538	51,692	68,260	84,442	102,206
Fifth Year, FT	4,586	4,175	4,055	5,206	5,520	5,706
Total Full-Time Undergraduates	194,727	201,099	257,835	311,237	365,117	403,812
Part-Time Undergraduates	14,149	16,689	19,844	22,843	32,227	31,945

In the past, the changes in enrollments could be handled because of the availability of additional faculty and the capacity of facilities already in place. This flexibility no longer exists and as a result faculty are overloaded, facilities are strained and the quality of engineering education is suffering.

.1.2 Engineering Graduate Enrollments and Degrees

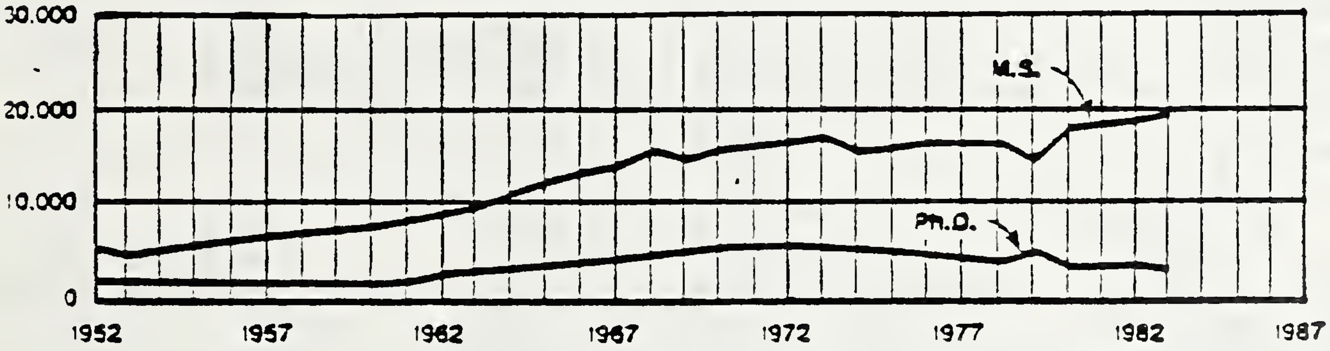
Master's degrees granted in engineering steadily increased from 3,636 in 1953 to 17,356 in 1972, and has stayed relatively constant since that time, increasing to 19,909 in 1983. The master's degree has become a reasonably common goal of engineers employed in reseach and development activities. Frequently these degrees are obtained on a part-time basis while the engineer is still employed full-time in industry.

Availability of a master's degree programs in the vicinity of an engineer's employment has become an important recruiting tool in industry.

Engineering doctoral degrees granted in the 1950's ranged from 500 to 700 per year. The post-sputnik interest in engineering created government support of graduate programs including many doctoral fellowships and research projects. Annual production of engineering doctorates reached 3,000 by 1969 and peaked at 3,774 in 1972. There was a steady decline to 2,573 in 1968, but that has now reversed and 3,023 degrees were awarded in 1983.

Of particular importance is the increase in foreign nationals receiving doctoral degrees. The percentage of foreign nationals receiving doctorates has risen from about 20% in 1971 to almost 40% in 1983. The trends in both master's and doctor's degrees granted are given in Figure 1-2.

Figure 1-2
GRADUATE ENGINEERING DEGREES EARNED
1952-1983



Full-time enrollments at the master's level gradually increased from 22,877 to 34,222 in the last decade. Full-time doctoral enrollments dropped from 14,802 in 1970 to 10,628 in 1974 and has increased to 16,549 in 1982. While part-time enrollments are not a significant factor at the undergraduate level, many engineers work on master's degrees on a part-time basis. Since 1969 part-time graduate students have decreased from 32,645 to 24,133 in 1978, and then rebounded to 31,656 in 1982.

Enrollment data for master's and doctoral programs is included in Table 1-2.

Table 1-2
GRADUATE ENGINEERING ENROLLMENTS 1970-1980

Engineering Student	Fall 1972	Fall 1974	Fall 1976	Fall 1978	Fall 1980	Fall 1982
Master's Degree, FT	22,877	21,999	25,516	26,060	29,870	34,222
Doctor's Degree, FT	13,460	10,628	10,963	12,321	14,465	16,549
Total Full-Time Graduate Students	36,337	32,627	36,479	38,381	44,335	50,771
Part-Time Graduate Students	24,940	27,572	26,842	24,133	28,250	31,656

There are a large number of engineering fields and Table 1-3 gives the breakdown of 1983 degrees by engineering disciplines and level and compares these to the corresponding degrees awarded in 1973.

Table 1-3
DEGREES IN ENGINEERING, BY CURRICULUM, 1973-1983

	BACHELOR'S		MASTER'S		DOCTORATE	
Curriculum	1973	1983	1973	1983	1973	198
Aerospace	1,326	2,207	608	512	181	9
Agricultural	454	704	152	146	68	5
Architectural	419	568	25	30	0	
Biomedical	103	577	123	178	46	5
Ceramic	191	294	39	55	22	1
Chemical	3,586	7,499	1,019	1,509	405	37
Civil	7,671	10,484	2,813	3,317	435	39
Computer	568	2,643	589	1,420	96	10
Electrical & Electronic	11,844	18,590	4,151	4,730	820	60
Engr. General	2,058	1,923	418	670	37	7
Engr. Science	1,144	1,298	756	408	307	17
Environmental	150	292	514	456	51	6
Industrial & Manufacturing	2,923	3,808	1,843	1,410	147	10
Marine, Naval Arch. & Ocean	413	699	196	163	18	1
Materials & Metallurgical	662	1,085	514	563	268	22
Mechancial	8,433	16,484	2,166	3,001	411	39
Mining & Mineral	333	1,019	101	280	31	5
Nuclear	324	420	402	311	115	11
Petroleum	328	1,420	95	227	17	1
Systems	180	210	430	430	72	5
Other	319	247	198	93	40	
Total	43,429	72,471	17,152	19,909	3,587	3,02

1.1.3 Women, Minorities and Foreign Nationals

Until the 1960's, engineering was mainly a profession composed of white males. In the mid-sixties efforts were made to attract more women to engineering programs and these programs met with gradual success. By 1982, 19,155 freshmen women were enrolled in engineering, out of a total of 115,303 freshmen, thus representing about 16.6% of the entering class. About 13% of the master's degree enrollees and 8% of the doctoral degree enrollees are women.

In the early 1970's a major effort was made to recruit more minorities to engineering. These efforts received major support by industry, government, engineering colleges and minority organizations. At first the efforts consisted primarily of recruiting and publicizing the profession. It was soon found the problem was much greater than a lack of engineering awareness on the part of prospective students. Many of the minority students were in inferior primary and secondary schools and seldom were they encouraged to take the mathematics and science courses that are preparation for collegiate engineering progrms. There is still great room for improvement, but considerable progress has been made. By 1982, 6,715 blacks, 4,421 hispanics, and 371 American Indians enrolled as freshmen representing 6%, 4% and 3% of the freshman class (Asian/Pacific minorities are normally not included in the minority effort since they are already well represented in the engineering profession). At the master's level the three pertinent minority groups total about 3% of the enrollment and the group total enrollment is only 1.4% at the doctoral level. Enrollments of women and minorities in Fall 1980 are given in Table 1-4.

Table 1-4

ENGINEERING ENROLLMENT, FALL 1982
WOMEN, MINORITIES, AND FOREIGN NATIONALS

	FULL-TIME UNDERGRADUATE STUDENTS		All Part-Time	FULL-TIME GRADUATE STUDENTS				All Part-Time
	1st Year	TOTAL FULL		Mstrs. Deg.	Engrg. Deg.	Doc. Deg.	TOTAL FULL	
Women	19,155	62,428	4,251	4,226	133	1,252	5,611	3,255
Black	6,715	17,632	1,794	505	17	117	639	503
Hispanic	4,421	14,055	1,141	455	4	111	570	400
Asian/ Pacific	4,098	15,710	1,562	1,869	33	637	2,539	1,436
American Indian	371	1,081	145	85	--	4	89	64
Foreign National	4,925	23,638	1,444	10,787	173	6,805	17,765	2,678
Total All Students	115,303	403,812	31,945	33,522	700	16,549	50,771	31,656

Degrees earned in 1982 by women and minorities are shown in Table 1-5.

Table 1-5
DEGREES EARNED 1982
WOMEN, MINORITIES

	Bachelor's	Master's	Doctorate
Women	8,140	1,549	126
Black	1,644	188	11
Hispanic	1,608	218	26
Asian/Pacific	2,577	850	124
American Indian	91	15	2
Total All Graduates	66,990	18,543	2,887

At the bachelor's degree level women receive 12%, Blacks 2.5%, Hispanics 2.5% and American Indians 1% of the total. The percentages at the master's level are: women 8.4%, Black 1.0%, Hispanics 1.2% and American Indians 0.1%. At the doctorate level the percentages are even smaller as follows: women 4.3%, Blacks 0.4%, Hispanics 0.9%, and American Indians 0.1%.

Women and minority graduates are highly sought after by industry. Opportunities for them are excellent. Competition is particularly intense at the doctoral level since universities are also seeking women and minorities as role models for their students.

The situation is quite different when foreign nationals' enrollments and degrees are tabulated. Table 1-4 shows that foreign nationals represent 6% of the total undergraduate enrollment. At the graduate level 32% of all full time master's degree enrollees and 41% of all doctoral enrollees are foreign nationals. In 1983, foreign nationals earned 8.4% of all B.S. degrees, 25.8% of all M.S. degrees and 39.6% of all doctorate degrees in the various engineering disciplines. It is obvious, therefore, that at the graduate level a major part of the effort is involved in the education of foreign nationals.

1.1.4 Demand for Engineering Graduates

Recruitment of engineers reached a low point in the early 1970's. This was due to the cutbacks in the space program and a general slowdown of the economy. When this occurred, engineering enrollments plummeted. As the economy improved, the number of engineering graduates fell considerably and the supply of engineers dropped well below the demand. As this became publicized, high school graduates flocked to engineering and enrollments increased rapidly. The rapid increases in salaries (to approximately $27,000/yr) is excellent evidence of the continuing value of engineering graduates.

In 1981 engineers in almost all fields were heavily recruited. Due to the recession, public works programs were cut back and thus Civil Engineering was the first field to experience a softening in demand. Due to the energy shortage in the mid-1970's, a great demand was experienced in Chemical

Engineering. As a result, students entered this field in far greater than usual numbers. B.S. degrees in Chemical Engineering went from approximately 3,000 in 1975 to 7,500 in 1983. Unfortunately, by 1982, Chemical engineers were not in high demand due to the temporary alleviation of the energy shortage. This provides an excellent example of the "out of phase" time delay in the supply-demand picture. It is a phenomenon frequently referred to as "ratcheting".

In Mechanical Engineering the demand nas began to increase, and although enrollments and degrees in Electrical Engineering increased dramatically there are no indications that demand is coming closer to being met. (Computer Engineering is included within Electrical Engineering.) B.S. degrees in Electrical Engineering and Computer Engineering have increased from approximately 10,000 in 1971 to 21,000 in 1983.

A recent National Science Foundation study projecting recruiting for 1984 indicated that Computer Engineering, Electrical Engineering and Manufacturing Engineering would be high demand disciplines.

.1.5 Shortage of Faculty

The shortage of faculty is a very serious problem for engineering education today. Estimates of the present number of faculty positions open in existing engineering schools range from 1,200 to 1,600 positions. Recruitment of faculty is difficult even in the most prestigious engineering schools. This shortage comes at a time when the percentage of doctoral candidates who are U.S. citizens is at an all-time low. Competition for these new doctoral graduates from industry is intense. Not only are they offered much higher salaries than those in academe, but usually research facilities are far superior in the many high technology companies recruiting these new doctoral graduates. The same factors of salary and facilities are also responsible for a number of experienced engineering faculty leaving the universities to accept challenging and high paying positions in industry.

It should be noted that the open faculty positions cited above are the number of budgeted positions vacant. In many schools enrollments have doubled, but the number of budgeted positions has not increased proportionately because university administrators are reluctant to add positions to departments that are unable to fill them. It is estimated that the true shortage of faculty is far greater than cited above and as a result faculty are greatly overloaded. Quality has thus suffered, as faculty time to advise students, participate in graduate and research programs and other professional activities has become limited.

Because the overload makes it almost impossible for faculty members to perform with the excellence that they desire, and because faculty salaries are not competitive with those paid in industry, many faculty members are leaving the teaching profession to accept positions in industry. This adds to the overloading and shortage of faculty.

1.1.6 Facilities and Equipment

Most engineering colleges have facilities to teach a much smaller engineering enrollment than now exists. In order to handle the present surge of students, many engineering colleges have greatly increased class and laboratory group size. The overcrowding has caused a number of schools to limit their enrollments in order to provide adequate instruction and safe laboratory experiences.

Equipment obsolescence has become a major problem. Most laboratory equipment in the colleges is not state-of-the-art equipment. It is estimated that the average age of university instrumentation is at least twice as old as that found in industry. This is patricularly true of research laboratories in universities versus modern industrial or governmental research labs.

During the past decade the undergraduate laboratory equipment holdings of engineering colleges have steadily lost ground to rapid obsolescence and inflation. Today the job of restoring these laboratories to something near state-of-the-art is one of enormous proportions. Texas A&M University has shown that based on an extrapolation of the needs of the nine engineering colleges in Texas, the total cost of updating the undergraduate laboratories nationwide is $1.0096 billion. In a more recent study, the National Society of Professional Engineers concludes that an expenditure of $1.2 billion would restore undergraduate teaching laboratories to 1971 status but that an additional $1 billion would be required for additions to laboratory facilities to accommodate the increase in student numbers since 1971.

Schools in the state of Michigan estimate that $86 million is needed for equipment in "catch up funds" and an additional $10 million on an annual basis for the engineering schools to "keep up". Schools in the state of Georgia document a "catch up" need immediately of $16.5 million and a recent NSF study of 43 research universities indicates that 25% of their laboratory equipment is obsolete and only 16% of their equipment is state-of-the-art.

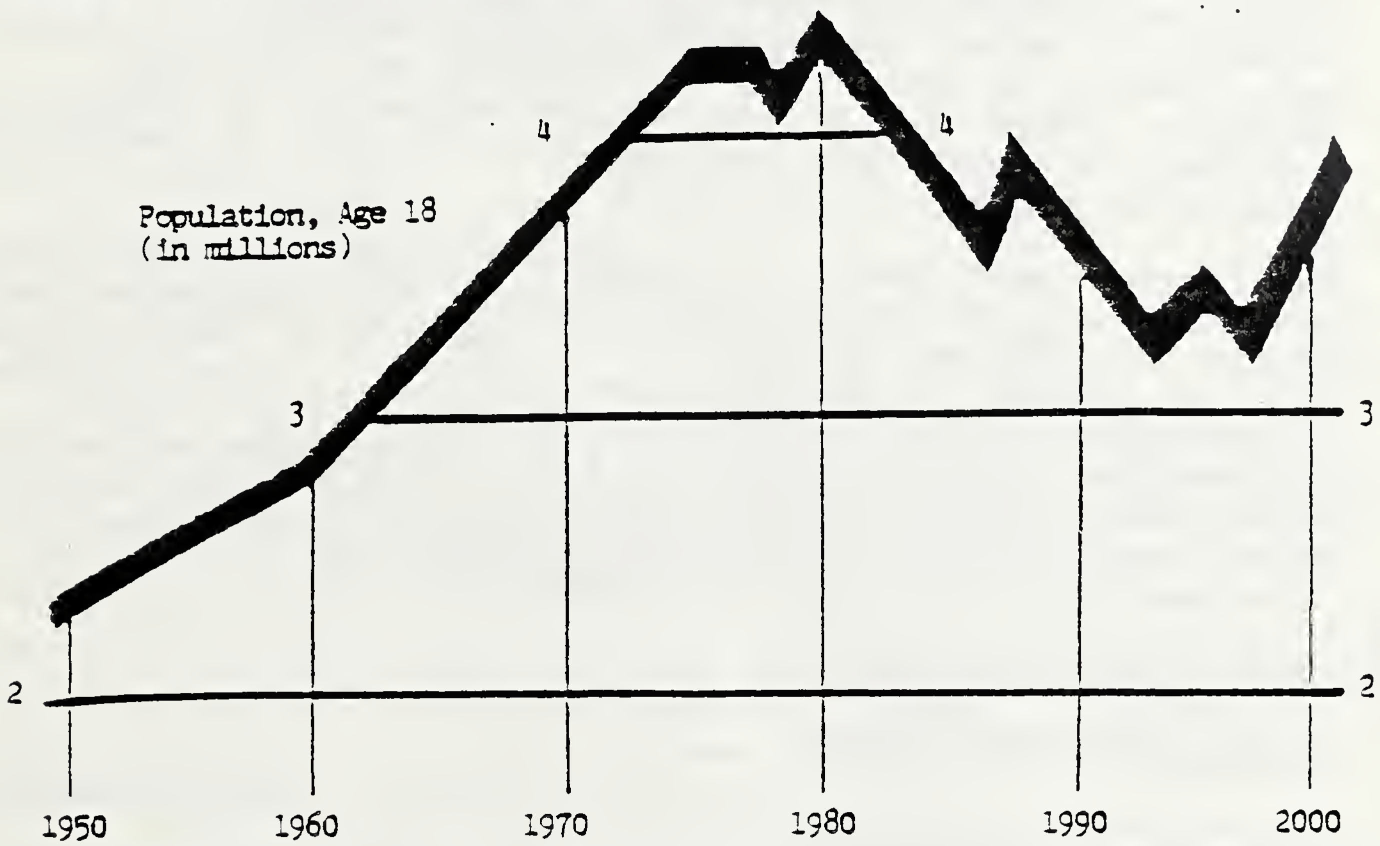
Estimates to correct this problem range from one billion to two billion needed on a national level to bring equipment quality to desirable modern levels.

1.1.7 Applicant Pool

Engineering enrollments were able to increase as they did in the 1970's because the number of college age students was increasing. Eighteen year olds increased from 3.7 million in 1970 to 4.2 million in 1980. This age group will drop to 3.4

million in 1990 and further drop to 3.2 million in 1994 before starting to increase again. Thus for engineering enrollments to remain at the present level it will mean a greater percentage of college age students will have to select engineering. Increases in engineering enrollment will only be possible if a much larger number of women and minorities elect engineering as their academic choice.

Figure 1-3 graphs the number of 18 year olds in the United States from 1950 to the year 2000.



Source: Change Magazine, March 1983

1.1.8 Summary of National Scene

In 1984 many factors have combined to cause a "crisis in engineering education". This crisis is well recognized not only by educators, but by people in government and industry. The principal factors involved are:

- Burgeoning undergraduate enrollments that have caused overcrowding in classrooms and laboratories.
- Graduate enrollments of U.S. citizens leveling, with enrollments of foreign nationals increasing and approaching 40% of the total at the doctoral level.
- Shortage of faculty, with an estimate of 1,200 to 1,600 unfilled positions at this time.
- Demand for engineering graduates in several fields far greater than the supply.

- Women and minorities still not adequately represented in the field of engineering.
- Facilties and equipment inadequate and outmoded.

1.2 Massachusetts Overview

Engineering education is extremely important to Massachusetts. It not only provides outstanding opportunities for high school students to select an important profession but it is also a major factor in satisfying the needs of Massachusetts industry. High quality engineering education is essential to the state in attracting new industry and even in keeping the industries already in the state.

The factors that affect engineering education on a national level are all present in Massachusetts, and influence the status of engineering education in the state. These factors will be covered in the following sections. In many states engineering education is dominated by one or two state engineering schools. Massachusetts has a number of independent engineering schools that by virtue of their number and size have a major impact. Therefore separate sections follow covering the public and independent sectors.

1.2.1 Public Universities

- Degree Programs Offered

The state of Massachusetts has engineering programs at the following institutions:

University of Massachusetts-Amherst (UMA)
University of Lowell (UL)
Southeastern Massachusetts University (SMU)
Massachusetts Maritime Academy (MMA)

Programs in Civil, Electrical and Mechanical Engineering are offered at Amherst, Lowell and SMU, with Chemical Engineering offered at Amherst and Lowell. A number of other engineering programs are offered depending on the interest and faculty expertise available at the institution. Amherst has had degree programs at the doctoral level as well as the master's and bachelor's level. Lowell has offered programs at both the master's and bachelor's level but now has a master's level program in Electrical Engineering.

Engineering Technology bachelor degree programs are offered by Lowell and SMU in several different fields.

The only engineering degree offered by the Massachusetts Maritime Academy is the Marine Engineering bachelor's degree. A complete listing of engineering degrees offered by the engineering schools of Massachusetts is given in Table D-1 (appendix D) and a similar listing of engineering technology degree programs is given in Table D-2 (appendix D).

- Undergraduate Enrollments and Degrees

Massachusetts has engineering degree programs at four of its public institutions. Undergraduate engineering enrollments at these institutions are given in Table 1-6, showing the changes in a five year period.

Table 1-6
UNDERGRADUATE ENGINEERING ENROLLMENTS
PUBLIC INSTITUTIONS

	77-78	82-83
University of Lowell (day)	2,115	3,013
(evening)	885	995
University of Massachusetts-Amherst	1,694	2,246
Southeastern Massachusetts University	759	989
Massachusetts Maritime Academy	643	615
Total (Public)	6,096	7,858

Massachusetts Maritime Academy has kept its enrollment relatively constant in its single engineering program, Marine Engineering. The other three schools have all been subject to increasing enrollment pressures at the undergraduate level. If the enrollments at Massachusetts Maritime Academy are excluded, it is noted that the undergraduate enrollment increased from 5,453 to 7,243 in the five year period cited. This represents a 33% increase in undergraduate enrollments. The year-by-year enrollments for all institutions are given in Table D-3 (appendix D).

Although enrollments are an indicator of size, the important factor in fulfilling a school's mission is the number of degrees earned. This information is given in Table 1-7, again showing the changes in a five year period.

Table 1-7
UNDERGRADUATE ENGINEERING DEGREES
PUBLIC INSTITUTIONS

	77-78	82-83
University of Lowell	338	500
University of Massachusetts-Amherst	301	447
Southeastern Massachusetts University	108	199
Massachusetts Maritime Academy	122	112
Total (Public)	869	1,258

Again excluding Massachusetts Maritime Academy, it is noted that engineering bachelor's degrees have increased from 747 to 1,145 in the five year period cited. This represents a 53% increase in bachelor degree production.

A total of 10 different bachelor's programs are offered by the public engineering schools. Electrical (including computer) Engineering is the largest. The total number of degrees conferred by the public institutions in each of the degree classifications is given in Table D-5 (appendix D).

It should be noted from Table D-5 that Electrical (including Computer) Engineering bachelor's degrees increased from 175 to 371 in the six year span cited, for a 112% increase. Mechanical Engineering bachelor's degrees increased from 157 to 261 for an increase of 66%. Civil Engineering bachelor's degrees actually decreased in number during this same period.

- Graduate Enrollment and Degrees

Graduate enrollments at the public institutions are given in Table 1-8 showing the changes in a five year period.

Table 1-8
GRADUATE ENGINEERING ENROLLMENTS
PUBLIC INSTITUTIONS

	77-78	82-83
University of Lowell (day)	526	626
(evening)	509	537
University of Massachusetts-Amherst	241	252
Southeastern Massachusetts University	10	15
Total (Public)	1,286	1,430

Although it was previously noted that undergraduate enrollments increased by 33%, the graduate enrollments increased by only 11%. Year by year enrollments are given in Table D-3 (appendix D).

Since many graduate students pursue their studies on a part time basis, enrollment statistics do not give as good an indication of mission fulfillment as the degree statistics. The figures for degrees are given in Table 1-9 using the same five year span.

Table 1-9
GRADUATE ENGINEERING DEGREES
PUBLIC INSTITUTIONS

	Master's		Doctorate	
	77-78	82-83	77-78	82-83
University of Lowell	44	94	0	0
University of Mass.-Amherst	83	89	24	26
Southeastern Mass. University	6	6	0	0
Total (Public)	133	189	24	26

Although it was noted that bachelor's degrees increased by 53%, master's degrees increased by 42%, but doctorate degrees increased by only 8%. The year by year statistics for graduate degrees earned are given in Table D-4 (appendix D).

The total number of degrees in each of the designated degree classifications is given in Table D-5 (appendix D). A further breakdown by institutions, as well as by area of specialization is given in Table D-6 (appendix D).

- Visits to Public Institutions

Each of the public institutions was visited by a team of engineering educators chaired by Dr. Edward Lear, Executive Director of ASEE. Also on the team were Dr. Robert Page, recent chairman of the National Engineering Faculty Shortage Project and Dean of Engineering at Texas A&M University and Dr. Richard Ungrodt, Vice President of Milwaukee College of Engineering and President-Elect of ASEE. One additional team member scheduled to participate was unable to do so because of illness. The team was accompanied by Dr. Joseph C. Hogan, author of this report and Dr. Claire Van Ummersen of the Board of Regents Office. The team consulted with administrators and faculty at the schools. The report of the team is included as appendix A and will be referred to in later sections of this report.

1.2.2 Independent Universities and Colleges

- Degree Programs Offered

The following independent institutions in the state of Massachusetts offer engineering degree programs:

Boston College
Harvard University
Massachusetts Institute of Technology
Merrimack College
Northeastern University
Tufts University
Western New England College
Worcester Polytechnic Institute

Engineering technology degrees are offered at the following independent institutions:

Central New England
Suffolk University
Wentworth Insititute of Technology

A complete listing of the engineering degrees offered by the above schools is given in Table D-1 (appendix D) a similar listing of engineering technology programs is given in Table D-2 (appendix D).

- Undergraduate Enrollments and Degrees

Massachusetts is atypical in that it has a such a large number of independent institutions offering engineering programs. Undergraduate engineering enrollments at these institutions are given in Table D-3 (appendix D). Several schools have large 1982-83 enrollments (Northeastern U. - 4,154, MIT - 3,189, WPI - 1,750 and Boston U. - 1,629). Of particular importance is the growth in enrollment from 7,600 to 12,000 undergraduates between 1977-78 and 1982-83. This represents an increase in enrollment of 66% in the independent institutions. This is twice the growth rate experienced in the public institutions.

The bachelor degree production over the same five year period is given in Table 1-10.

Table 1-10
INDEPENDENT INSTITUTIONS
UNDERGRADUATE DEGREES

	77-78	82-83
Boston University	65	229
Central New England	40[1]	123
Harvard University	6	4*
Massachusetts Institute of Technology	552	742
Merrimack College	22	34
Northestern University	344	604
Tufts University	126	174
Wentworth Institute of Technology	100[1]	141
Western New England College	58	73
Worcester Polytechnic Institute	300*	404
Total (Independent)	1,613	2,528

* Estimated
[1] Engineering Technology Programs

It is noted that the number of bachelor's degrees earned has increased by 57% during the five year span cited. This is quite comparable to the 53% experienced in the public institutions.

Many different degree specialities are offered by the independent institutions. The number of degrees given by each institution in each of several specialities, is given in Table D-6 (appendix D).

- Graduate Enrollment and Degrees

Graduate enrollments are given in Table D-3 (appendix D). As in the case with undergraduate enrollments, there is a wide range in the size of the various programs. MIT dominates the statistics with a total of 1,799 graduate students. This is more than 50% of all graduate engineering students in independent institutions. Northeastern University has 591 graduate students and Worcester Polytechnic Institute has 290, all others had less than 200 in the 1982-83 year.

Graduate enrollments at independent institutions increased from 2,850 to 3,065 in the five year span for an increase of only 7.5%. Graduate degree production by the independent institutions, broken down by master's and doctoral levels, are given in Table 1-11.

Table 1-11
INDEPENDENT INSTITUTIONS
GRADUATE DEGREES

	Master's		Doctorates	
	77-78	82-83	77-78	82-83
Boston Unviersity	20	73	0	0
Mass. Institute of Technology	517	602	177	171
Northeastern University	177	256	2	2
Tufts University	28	50	1	3
Western New England	2	17	0	0
Worcester Polytechnic Inst.	50*	64	2*	3
Total (Independent)	794	1,062	182	179

* Estimated

Master's degree production thus shows an increase of 34% while there is actually a decrease in doctorate production. M.I.T. dominates the statistics at the graduate level giving approximately 50% of the total master's degrees and 83% of the total doctoral degrees given by all institutions in the state, both public and independent.

The independent institutions are a major resource to the state, as illustrated in Table 1-12, which gives a breakdown of engineering degrees in 1983 by the independent and public universities.

Table 1-12
1983 DEGREES GRANTED

	Public	Independent	Total
Bachelor's	1,258	2,250	3,778
Master's	189	926	1,115
Doctorates	26	179	205

Thus it is noted that independent schools produce 67% of the bachelor's degrees, 83% of the master's degrees and 87% of the doctoral degrees given in the state.

- Visits to Independent Institutions

Most of the independent institutions were visited by Dr. Joseph C. Hogan, author of this report and Dr. Claire Van Ummersen of the Board of Regents Office. These institutions included M.I.T., Boston University, Western New England College, Merrimack College, Northeastern University, Tufts University and Worcester Polytechnic Institute. Dr. Richard Ungrodt, of Milwaukee College of Engineering, visited Wentworth Institute of Technology. Central New England College and Suffolk University, both with engineering technology programs, did not choose to be visited. Wang Institute has been recently established and offered a master's degree program in Software Engineering. Harvard University has only a very small number of engineering students. These institutions were not visited.

Comments regarding the institutions visited are contained in appendix B.

1.2.3 Collaborative Engineering Programs

As shown in the previous section both the public and independent institutions have responded to the increased demand for engineering education. The cost of education is still a major factor in discouraging economically disadvantaged students from continuing toward an engineering degree. This is particularly true in the greater Boston area where no state supported baccalaureate engineering programs are available. Students have the opportunity of taking the first two years of an engineering program at the University of Massachusetts - Boston and then transferring for the last two years to one of the three state schools or to an independent school in the Boston area. Transfer to a state university involves the higher cost of living away from home, while transfer to a local independent university involves the higher tuition costs of those institutions.

In 1983 a collaborative Engineering Program was begun that permitted students to take the first two years of an electrical engineering program at the University of Massachusetts-Boston and then transfer to one of four Boston area independent institutions, with the student paying approximately the same tuition that would have been paid to a state university. The difference in tuition is paid to the independent institution by a special fund set up by the state. The consortium of schools includes the University of Massachusetts-Boston, Boston University, Northeastern University, Tufts University, and Wentworth Institute of Technology.

This program was established to accomplish the following objectives:

- provide more electrical engineers to help satisfy the demand by Massachusetts industry for a particular engineering discipline;

- provide access to electrical engineering degree programs for economically disadvantaged students in the Greater Boston Area;
- to attract more minorities and women to electrical engineering programs.

The first transfers were accepted at the participating universities in fall of '83. This first group consisted of a total of 14 students. As the program has become better known it is attracting more students and a much larger number of students are now requesting entrance to the program. By Fall '84 approximately 40 students will have transferred from the University of Massachusetts/Boston to the independent engineering schools in the consortium.

This program permits the student to complete the degree in four years by virtue of the 2+2 nature of the program. Students who transfer to Northeastern University enter a cooperative program and hence take a total of five years, in what is a 2+3 program.

Initial students entering the program are paying $2,500 annual tuition with a state grant-in-aid paying an additional $5,000 toward annual tuition. Northeastern University grant-in-aid is pro-rated over a three year period. To continue in the program students must maintain academic standing necessary for graduation and upon completion of the degree must work in industry in the state of Massachusetts or be liable for repaying the grant-in-aid funds back to the state.

The program is small at this time but shows excellent promise of meeting its objectives.

1.2.4. Community Colleges

- Access

One of the major objectives of the community colleges is to provide students with the opportunity to obtain two years of collegiate work without having the additional expenses of having to live away from home. Students pursue the two year program in preparation for transfer to a four year school or may pursue a two year terminal program that is career oriented. The community colleges thus provide access to collegiate education to students who might not otherwise be able to afford it.

- Programs Offered

All of the community colleges offer the mathematics and science courses that are of a remedial nature. Beyond that point there is a wide variation in offerings. Some of the colleges give only part of the mathematics (starting with calculus), chemistry (with laboratory) and Physics (calculus based) needed for the first two years of an engineering program. Other colleges give all the mathematics and sciences needed for transfer in addition to some of the basic engineering courses. A few of the colleges give all the courses needed for transfer including the required engineering courses and associated laboratories. These schools usually have articulation agreements with one or more of the state universities to facilitate the transfer process.

- Undergraduate Enrollment and Associate Degrees

Enrollments at the community colleges are given in Table D-7 (appendix D). Associate degree statistics are given in the same table.

Because the community colleges provide greater access than more distant universities, one would expect a sizeable enrollment in those groups not adequately represented in engineering schools (i.e. women and minorities). Unfortunately the records show that a disappointingly small percentage of minorities enroll in engineering programs in the community colleges. The statistics showing breakdowns by sex and race are given in Table D-8 (appendix D).

- Visits with Community College Representatives

Meetings were held in Springfield and Wellesley with representatives of nine community colleges. Dr. Richard Ungrodt, Dr. Joseph Hogan and Dr. Claire Van Ummersen discussed programs, problems, goals etc. with representatives of each of the institutions. Appendix C provides comments on these meetings and will be referred to later in this report.

1.2.5. Demand By Industry

In Massachusetts, engineering education is especially important because the state must have a steady flow of engineering graduates to meet the present and future needs of industry, to attract new industries to the state and to keep Massachusetts competitive with other states.

Educational planning which considers the delicate balance between supply and demand for engineers will be very important. Recognizing this need the Board of Regents recently requested a report from its Ad Hoc Committee on Engineering Manpower. This committee concluded that no methodology now exists for satisfactorily predicting the balance between supply and demand. The committee recommended that a monitoring system be put in place to track data in the Commonwealth on supply and demand for engineers.

At the present time its appears that there is an excess supply of chemical and civil engineers. Some division in opinion exists as to whether or not the supply of Mechanical Engineers has kept up with the demand. All who have studied the problem have concludedthat the demand for electrical engineers exceeds the supply. It will be necessary for industry to increase its recruitment of electrical engineers from outside the state. An increase in the quality of the engineering schools will also attract more outstanding scholars from other states many of whom will stay in Massachusetts upon completion of their studies.

Supply-demand considerations are very complex because so many factors must be considerd. These include the student applicant pool, the state of the economy, changing technologies and industrial geographical shifts. Any of these can upset predictions. In view of the above the Ad Hoc Committee concluded that "emphasis over the next few years should be placed on improving the quality of undergraduate engineering as opposed to further expansion of enrollments. This will give time to better assess the future needs for engineering educational capacity."

Of very serious concern to Massachusetts is the decrease in the number of doctorates granted statewide. The demand is extremely great for engineers with doctoral degrees. The limited availability of such people, in turn, limits the expansion of engineering educational programs. Industry is also limited if doctorate level engineers are not available for research and development activities.

It should be pointed out that additional capacity in the existing engineering schools or the establishment of new engineering schools may not materially increase the number of graduates. The existing engineering schools project little or no growth in the next five years and there are some indications that almost all of the high school students with both a desire and capability to study engineering now have access to such an education.

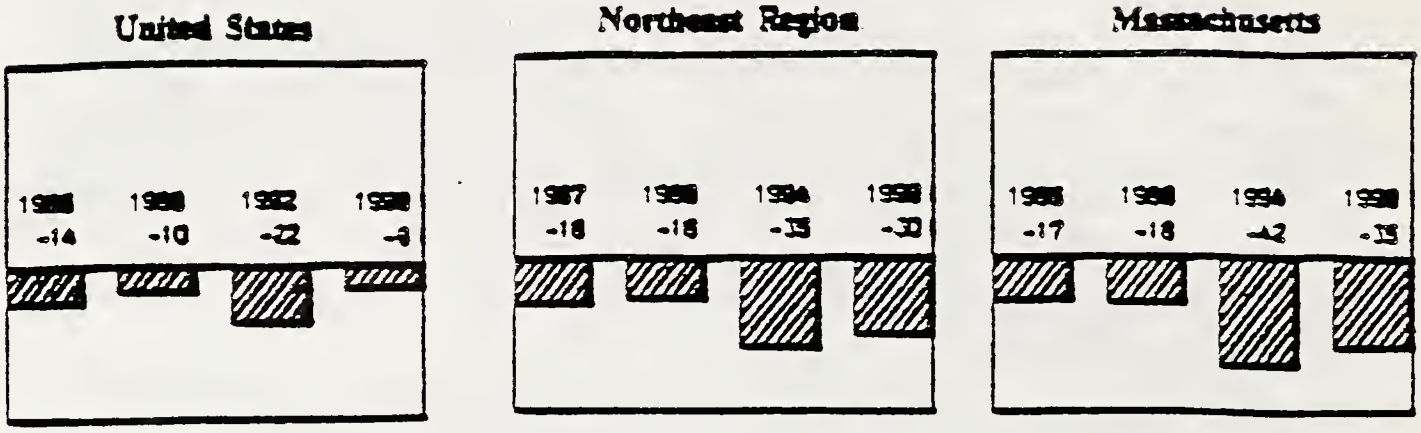
The report of the Board of Regents Ad Hoc Committee on Engineering Manpower in contained in appendix E.

.2.6. Applicant Pool

Section 1.1.7 discussed the applicant pool at the national level and indicated a sharp decrease in the number of 18-year-olds. The decrease is even more drastic in New England and Massachusetts. Using 1981 as a base year, the change in the number of high school graduates as projected in a report of the Western Interstate Commission for Higher Educaton (WICHE) is given in Figure 1-4.

Figure 1-4

Pattern of Projected High School Graduates
1981 - 2000, Northeast States
Percentage Change from 1981



More complete and detailed information is contained in the October 1983 report to the Board of Regents titled "Shaping the Future of Massachusetts Higher Education: Demographic Change and Enrollment Prospects."

While there appears to be enough applicants currently qualified for engineering schools to fill the schools to capacity, this must be monitored carefully as the number of eighteen-year-olds decline in Massachusetts. A larger proportion of high school graduates, including women and minorities, must be awakened to the career opportunities available to them in engineering. To even maintain current enrollment, capturing a larger share of the applicant pool will be required in the future. If the quality of the elementary and high schools can be improved, this will increase the percentage of students capable of pursuing an engineering degree.

If the quality of the universities in the state is improved, the number of applicants from outside the state of Massachusetts will probably increase.

1.2.7 Summary of Massachusetts Scene

The same factors affecting engineering education on the national level bear on the engineering educational enterprise within the state of Massachusetts. Most of the engineering schools are experiencing the following:

- Excessive undergraduate enrollments.
- Overcrowding in the classrooms and laboratories.
- Shortage of faculty, due to difficulty in recruiting or lack of funded positions.
- Laboratory equipment inadequate and outmoded.

- Lack of growth in graduate programs.
- Difficulty in recruiting minorities (and to a lesser extent women) to the field of engineering.

The state as a whole is experiencing the following:

- Shortage of engineering graduates, particularly in electrical and computer engineering areas.
- Lack of a proven supply-demand model for engineering manpower.
- Concern over the quality of elementary and high school educational quality.

M.I.T. occupies a unique position and as such does not experience some of the conditions cited above. For example, it controls enrollments and is able to attract top candidates as undergraduates, graduate students and even faculty.

CHAPTER II

NEED FOR EXCELLENCE

2.1 Factors that Influence Quality

Improvement in the quality of engineering education should be a foremost goal of the state. This is, of course, important to the students in the programs, but it is also important to the present and future well-being of the economy of Massachusetts, due to its importance in attracting and keeping high technology industries. Industry of this type looks for high quality engineering schools to provide graduates and educational opportunities for their engineers, particularly at the graduate levels. They are also interested in the research of such institutions and the quality of the faculty. Faculty of such institutions may provide consultants to aid a company's research and development effort. Companies are also seeking out engineering schools that will undertake research activities. For the above reasons, excellence in engineering education should be a goal of the state and each of the engineering schools in Massachusetts.

2.1.1 Quality of Students

A school with a national reputation has little difficulty recruiting excellent students since such schools are sought out by the best high school graduates. For those schools depending on a flow of entering students from nearby, the quality of the entering student is greatly affected by the quality of education in the elementary and high schools of the region. Most of the engineering schools in the state admit a majority of freshmen from Massachusetts. Some of the schools can be very selective in admissions and hence the quality of the student overshadows the quality of the educational process to which that student was exposed. Other schools purposely provide opportunity for a wide range of high school graduates, and for these schools it is difficult to overcome the marginal background of some of its entering freshmen. Massachusetts has some excellent school systems, but marginal school systems must be improved. Unfortunately these are frequently in the areas where the economically disadvantaged live.

2.1.2 The Undergraduate Experience

The quality of the undergraduate programs is affected by the quality of the faculty, program content, facilities and equipment. A faculty that is overextended due to teaching load, class size and understaffing can not perform to the standards that each member would prefer. The state supported engineering schools are not being provided the resources to deliver the quality program desired and attainable by the faculty in place. Some of the independent engineering schools are also having great difficulties obtaining the needed resources. This is particularly true in smaller institutions.

2.1.3 Graduate Education and Research

The need for graduate engineering education is great and a separate chapter follows on part-time off-campus programs. Quality graduate education not only supplies a needed program for students but is an important factor in attracting high quality faculty. Research associated with graduate programs is an important measure of their quality of graduate programs.

2.1.4 Availability of Resources

Quality programs depend completely on the availability of resources supplied to the engineering schools. Independent schools in the state range from those with large endowments to those that receive 98% of their funds from tuition income. The state supported schools have not received the resources needed to improve quality. Sometimes this lack is due to policies on the local campus, sometimes it is due to lack of appropriations. Table D-9 (appendix D) illustrates the great difference in resources supplied to the various engineering schools of the state. Note particularly the inadequacy of staff support (secretarial and technicians) at the state supported engineering schools.

During the course of visits to the schools many examples of the lack of resources was evident. The examples include:

- University of Lowell: In spite of having the highest percentage of engineering students of the state universities, this institution receives the lowest appropriation per student from the state. As a result of this, support services suffer. An example of this is in the electrical engineering department where there is only one secretary for 30 faculty members.

- University of Massachusetts-Amherst: In spite of having a large undergraduate, graduate and research program the campus administration has allocated only $50,000 annually from the maintenance budget for the last several years to be used by the college of engineering to purchase capital equipment including laboratory equipment. This is completely inadequate.

- Southeastern Massachusetts University: Although a major computer and 100 terminals were received on campus, installation was delayed more than six months due to the lack of technicians needed to install it and the failure of administration to support alternatives.

2.2 Attaining National Prominence

Although the previous section stressed quality at all levels it is sometimes possible to have high quality that goes unrecognized. The factors that affect this recognition should therefore be examined.

The first priority of an engineering school should always be the providing of high quality undergraduate engineering education to its students. The Bachelor's programs in engineering are the base upon which engineering schools are built. Excellence of the undergraduate program usually becomes well-known in the local and occasionally the regional areas served by the institution. Unfortunately, such excellence is rarely acknowledged at the national level. For example, Harvey Mudd College on the West Coast and Rose Hulman College in the Midwest have excellent undergraduate programs but are not well-known nationally. The undergraduate program unfortunately is, therefore, not a means to achieve national prominence.

The size of a program, in terms of enrollment, is another factor frequently considered in building a national reputation. A larger size frequently leads to a better quality of undergraduate program because of greater efficiencies built into the system. For example, class sizes can be controlled so that teaching is efficient providing the most effective learning experiences for the students. Many more electives can also be offered in the senior year with these electives being sufficiently populated to still provide efficient use of teaching resources. Larger enrollments in programs result in more graduates and this is an important factor to industries recruiting engineers in that state. Thus size may be an important factor in the efficiency and cost of providing engineering education as well as improving the quality of such education. However it, too, is not a major factor in achieving a national reputation. California Institute of Technology is an example of a school with an extremely fine and national reputation but with an extremely small undergraduate program. Likewise large enrollment in an undergraduate program is not necessarily a leading factor in attracting industry to the region near the school. For example, Texas A&M University, Virginia Polytechnic Institute and University of Missouri at Rolla are three of the larger undergraduate programs in the country, and yet have essentially little or no industry surrounding them.

The single most important factor in determining national reputation is the quality of the graduate programs and the concomitant research done at those institutions. The American Council on Education has made major studies on the quality of graduate programs. These reports ranked the quality of the doctoral programs at institutions as well as the quality of the faculties. The top-ranked engineering schools in these reports are uniformly the same institutions that enjoy the best overall national reputations. One must conclude from that, that national reputation is strongly dependent upon the quality of research and graduate programs at engineering schools. Included in the top grouping are independent institutions such as M.I.T., Stanford, California Institute of Technology and state institutions such as the University of California, University of Michigan and University of Illinois. These schools are all well recognized nationally for the excellence of their engineering programs. They are both public and independent, large and small, but all are top quality graduate and research institutions.

2.2.1 Importance of Research and Graduate Programs

While the previous section stressed the importance of research and graduate programs on acheiving national prominence, there are a number of other advantages in building strength in research and graduate studies. The shortage of faculty at the national level has been stressed several times in this report. Recruiting for quality faculty is a very difficult task. Prospective faculty consider such things as salary, teaching loads, geographic locations, fringe benefits, and a number of other factors. Of great importance to prospective faculty is the opportunity to participate and contribute to on-going research programs. The better the quality of research and graduate studies at the institution, the easier it is to attract quality faculty.

The faculty that is excellent in research attracts a number of research grants. These research grants, in turn, provide for partial payment of the professor's salary proportional to the professor's effort on the research project. These salary funds provided by the grants are frequently referred to as soft money and this soft money is used by many institutions to hire additional faculty, thus providing strengths to the institution that would normally not be possible.

As a result of the research grant, faculty members usually publish the results in learned journals. This, in turn, enhances their reputation and that of the institution they represent. Research grants frequently provide funds for laboratory equipment, or for the maintenance of such equipment. The benefits of research thus make the institutions and the faculties more attractive to agencies and industries supporting the research, and therefore, increase the likelihood of gaining more grants to the institutions.

Because engineering bachelor degree graduates receive high initial salaries, graduate opportunities must be made as attractive as possible to them. Of prime importance is the financial support needed by engineering graduate students. A university with a high quality graduate and research program will also have many research grants that support the graduate students. Also industries that supply fellowship funds to institutions for the support of graduate students, do so primarily based on the reputation of the institution's graduate and research programs.

2.2.2 Research in Massachusetts Institutions

There is a wide range of activity in research at the engineering schools of Massachusetts. Table 2-1 gives a listing of research expenditures of the various schools taken from the 1983 data supplied to the American Society of Engineering Education and published in March of 1984.

Table 2-1
ENGINEERING RESEARCH EXPENDITURES
1982-83

Public Institutions	
University of Massachusetts Amherst	3,674,317
University of Lowell	1,142,000
Southeastern Massachusetts University	231,899
Independent Institutions	
Boston University	537,000
Massachusetts Institute of Technology	55,592,285
Northeastern University	2,057,960
Tufts University	477,000
Western New England College	17,000
Worcester Polytechnic Institute	4,263,000

A detailed listing showing the source of support is given in Table D-10 (appendix D) and another listing showing research support broken down by field of engineering is given in Table D-11 (appendix D). Most of the research support comes from the federal government and at most schools electrical engineering research receives the largest allocations.

2.2.3 Centers of Excellence

The state of Massachusetts is in the process of establishing several centers of excellence. The first of these is to be a Microelectronics Center. Preliminary discussions have also occurred concerning the establishment of a Photovoltaic Center and a Polymer Science Center. These centers should provide valuable learning experiences and research opportunities for students, as well as faculty, to interact with industry researchers in a supportive atmosphere. These centers should facilitate joint research and development ventures between universities and industries.

It should be noted that Massachusetts is not the only state providing funds for centers of excellence and similar approaches. The competition among states is great and stakes are high. Recently the highly sought after Microelectronics and Computer Technology Corporation picked Austin, Texas as its location. One factor involved the decision by the University of Texas to provide endowments worth $15 million for faculty members in its computer science and electrical engineering departments. Other states have made similar commitments to attract high technology industries.

2.3 Return on Investment

It is important that the state support quality at all levels of the educational system. It is particularly important that research and graduate programs in the engineering schools be adequately supported. Everything possible should be done to improve the research facilities and buy needed research equipment for the engineering schools. Great care should be taken in the recruitment of faculty so that those selected have outstanding potential for research as well as excellence in teaching at the undergraduate and graduate levels. Once the faculty at an institution has an outstanding reputation, it becomes easier to attract new young faculty to join them. Excellence begets excellence. It takes time to develop the critical mass to establish an excellent research reputation at an institution.

Maintaining a sufficient supply of engineering graduates from quality programs is essential to Massachusetts' capacity to attract new industries and keep the present industries in the state. An investment in engineering education will be regained many times over in new job opportunities, which will in turn translate into a healthier economy for the state.

CHAPTER III

CONTINUING EDUCATION FOR ENGINEERS

3.1 Needs of Industry

In a field governed by rapidly changing technology, continuing education is a critical component in satisfying the need for continued professional development of engineers. Many engineers satisfy this need by taking graduate courses as part of a master's degree program, while working in full time employment. The availabilty of such programs depends on the proximity of an engineering school or on the delivery of such courses from a remote location.

Massachusetts has many industries hiring large numbers of engineers. Of major importance to these industries is the ability to satisfy their manpower needs. Industries meet these needs by hiring engineering graduates, not only from Massachusetts, but from all over the nation. Since many of the new engineering graduates are interested in graduate programs, the availability of such programs becomes very important in the recruiting process. Industry thus needs these programs not only to satisfy the educational requirements of their engineers already employed, but also as an attraction for newly hired engineers. This attraction is related to the quality of the graduate programs available, thus high quality programs are imperative.

3.2 Evening Programs

The Boston area has long been served by Northeastern University's evening graduate programs. In addition to offering such courses on its main campus, Northeastern has established two suburban campuses for the offering of evening courses. These programs have been very well received, and a large number of engineers have obtained their master's degrees by this method. Recently Northeastern has begun an Industrial Fellowship Program. In this program the employee spends two days a week on the Northeastern campus for three quarters while working the other days of the week. The fourth quarter is spent in the company where the master's thesis is completed. This program is offered in electrical engineering in the areas of computer engineering or communications and signal processing and leads to the M.S. in E.E. degree. While not an evening program it provides a graduate program for the employed engineer with the complete cost borne by the employer and completion of the degree possible in one calendar year.

Recently Boston University also set up master's degree programs in engineering for employed engineers of the Boston area. Worcester Polytechnic Institute offers graduate degree programs at the master's level in an evening program. Courses are offered on the main campus and at four off-campus locations.

The University of Lowell offers an extensive evening program but the majority of the engineering related courses are in the engineering technology program.

SMU has a small master's level program in electrical engineering serving industries in the Southern Massachusetts region.

3.3 On - Site Programs

There is an increasing trend toward delivering graduate programs at the place of employment of the engineer. In some cases only the employees of the host company may attend and in other cases the industrial location is treated as an extension of the main campus of the offering university and any graduate students may attend.

3.3.1 Video Cassette Delivery

The University of Massachusetts-Amherst has a Video Instructional Program (V.I.P.) effort in which regular graduate courses are video taped and distributed to industrial sites. Employees can thus take the course at their place of employment. University of Massachusetts-Amherst has a goal of 1,000 course registrants per semester in this program. At the present time offerings are available leading to the Master's Degree in Electrical and Computer Engineering and Engineering Management.

Boston University has utilized videotaped lectures for two on-site graduate courses in engineering.

Massachusetts Institute of Technology has produced a number of complete courses on videotape through its Center for Advanced Engineering Study. These courses are available for purchase or for rental, primarily to other educational institutions or for industry since the cost is completelv prohibitive for an individual. M.I.T. does not offer academic credit with the videotaped courses.

3.3.2 On Line Television Delivery

In September, 1983, Northeastern University began live T.V. broadcasts of graduate courses directly into the plants of ten companies in the Boston area. These courses are broadcast during the day while on campus graduate students are simultaneously taking the course. Two special T.V. classrooms have been established on campus. The courses are microwaved to the Prudential Building Towers where they are rebroadcast over an omnidirectional antenna. Receiver antennas are located at the industrial plants. Telephone communications are maintained so that students at the industrial site can ask questions of the professor during the course of the lecture, providing interactive communications at all times. Couriers are used to collect and deliver homework. The students go to one of the suburban campuses to take the exams, which are given at the same time as the on-campus regular course exams. There are 200 students in the program and 10 additional companies are joining the program in Fall 1984. The companies permit the students to take courses during regular working hours and the companies pay for all costs of the program. Tuition is twice the usual tuition for a course. This approach to delivery of off-campus graduate programs shows great promise.

3.4 State Television Network

In 1982 the Commonwealth of Massachusetts authorized a statewide, multipurpose, educational telecommunications network. It further created the Massachusetts Corporation for Educational Telecommunications (MCET) to implement the network, giving the corporation broad authority to plan, create and operate a statewide telecommunications system. One of the purposes cited is to link higher education, school systems, libraries, and health institutions to the many potential users of telecommunications by establishment of a telecommunications network which would encourage and facilitate economies of scale and complementariness among such entities by providing a direct communications link, for education, information and data resource sharing. A board of directors has been established and staff has been appointed. The Corporation has been involved in planning and defining its role and must still be considered to be in its formative stage.

The availability of such a network has great potential for improving dramatically the delivery of continuing engineering education, including graduate programs at the master's degree level. This system provides the potential for interchange of courses among universities, remote delivery of courses from the campus to an industrial location or to a satellite campus, delivery of lower level engineering courses to community colleges and delivery of short courses. These possibilities should be explored jointly by the Corporation, the universities and technological industries.

3.5 National Technological University

The National Technological University (NTU) was incorporated in January, 1984. It plans to offer graduate courses by instructional television (ITV). Courses would be generated at one of the participating universities, and the participating university would be responsible for the grading of students enrolled in that particular course. NTU would keep a registry of all grades and the Master of Science degree in selected fields of engineering would be granted by NTU upon successful completion of all the required courses. Northeastern University and the University of Massachusetts have both elected to become participating universities and two other universities in Massachusetts are considering participation. It is an interesting approach and should be monitored to determine its effect, if any, on satisfying the needs for graduate programs in the state.

CHAPTER IV

INSTITUTIONAL PROGRAM DEVELOPMENT THROUGH 1990

4.1 Plans and Projections Through 1990

The last few years have been difficult ones for the engineering schools of the state. Enrollments have soared, faculty have been overloaded and resources have been limited. Demand for graduates has been great but has moderated in several fields. All of these problems have exacted a toll, and quality has been difficult to maintain. The schools have recognized the fact that the college-age population is decreasing and will continue to do so for the next ten years. Most of the schools have recognized that expansion of existing programs and establishment of new programs will not solve these problems. In general the schools are planning for improvement in quality.

4.2 Anticipated New Programs (Public)

4.2.1 University of Massachusetts - Amherst

The University of Massachusetts - Amherst is proposing no growth in undergraduate student enrollments. In fact, it is expected that the freshmen enrollment will be decreased as a matter of policy. Additional students will be accepted as transfer students after completing two years of preparation at a community college or other college. Thus, the number of graduates should remain approximately the same as the present, but the teaching will be concentrated more in junior and senior level classes.

The college has a five year goal of significantly increasing the size and quality of the graduate and research programs. The college hopes to double its graduate enrollment and to produce 50 PhD's annually and to attract $10 million annually for research.

The college is planning no new programs or degrees but will try to do everything possible to improve quality by solving its existing problems as follows:

- recruit and retain an outstanding faculty;
- decrease overcrowding in undergraduate classrooms and laboratories;
- add and improve both classroom and laboratory space;
- improve computer access;
- replace obsolete laboratory equipment and provide modern laboratories;

- emphasize graduate education;
- expand research; and
- obtain modern research buildings and equipment to support research effort.

4.2.2 University of Lowell

The University of Lowell is planning for no new degrees or programs at the undergraduate level in engineering or engineering technology. Emphasis is to be placed on growth of the master level graduate program and initiation of a Doctor of Engineering degree with a major in any of the current degree granting engineering disciplines. Another major thrust will be to obtain additional funding to improve the quality of the engineering college. This funding would be used to do the following:

- hire additional faculty;
- replace obsolete equipment;
- add state-of-the-art laboratory equipment and computing facilities;
- improve physical plant;
- improve support services;
- initiate Doctor of Engineering program

The only new program anticipated is the Doctor of Engineering degree program.

4.2.3 Southeastern Massachusetts University

Southeastern Massachusetts is planning for no new degrees or programs at the undergraduate level in engineering or engineering technology. Some expansion is planned in existing master's level graduate programs to better serve the needs of area industries. The only new programmatic thrust is the planning for a PhD. degree program in electrical engineering. The college has a major thrust to strengthen ties with regional industry particularly in the Electrical and Computer Engineering areas. Increased funding is sougnt for the following:

- additional faculty;
- merit raise funds;
- improved laboratory and computer equipment;
- increased M.S. offerings to employed engineers.

The only new program being proposed is the PhD. degree program in Electrical Engineering.

4.2.4 Massachusetts Maritime Academy

Massachusetts Maritime Academy is planning no new engineering programs. Major efforts in the immediate future will be the integration of the new vessel into the ongoing programs of the Academy.

4.2.5 University of Massachusetts - Boston

The University of Massachusetts - Boston has proposed offering the BS in Engineering Physics degree. Other planning is for improvements in the engineering transfer program, including upgrading of laboratory equipment.

4.2.6 Fitchburg State College

Fitchburg State College has proposed offering the following degree programs:

- B.S. in Electrical Engineering
- B.S. in Mechanical Engineering

4.2.7 Salem State College

Salem State College has proposed offering the following degree programs:

- B.S. in Civil Engineering
- B.S. in Computer Engineering

4.2.8 Westfield State College

Westfield State College has proposed offering the following degree programs

- B.S. in Microcomputer Applications Engineering
- B.S. in Microelectronics Engineering

4.2.9 Roxbury Community College

Roxbury Community College has proposed offering an A.S. degree for Pre-Engineering transfer.

4.3 Anticipated New Programs (Independent)

Most of the independent engineering schools do not anticipate adding new programs but instead are planning for improvement in quality of their present programs. All existing programs, just as in the public sector, will be modifying curricular content in response to new technological developments. The few exceptions to this are in the sections that follow.

4.3.1 Boston College

Boston College does not have an engineering program at the present time. There is now a proposal under review to initiate degree programs in electrical and computer engineering.

4.3.2 Boston University

Boston University has major plans for expansion of its engineering programs. A fund drive is underway to provide for expansion of the physical plant. Emphasis is being placed on distinctive programs in such fields as Bio-Medical, Computer, Manufacturing and Aerospace Engineering. Increased graduate course offerings to employed engineers are also planned.

4.3.3 Analogic Corporation

Analogic Corporation has requested degree authority to offer a M.S. in Engineering Management as a component of the articles of incorporation for the Gordon Institute of Advanced Technology.

CHAPTER V

OPPORTUNITIES FOR COOPERATION

One of the advantages of visiting with institutions throughout the State, is the possibility of obtaining an overview, not only of the institutions, but of how their interaction with one another. Several areas of possible cooperation became evident during the course of the study. These opportunities will be separately discussed in this section, with the hope that, where cooperation now exists, it will continue and, where it does not exist, institutions will consider participation in some of these activities with other institition.

5.1 Collaborative Program

The Collaborative Program is an excellent example of cooperation among institutions. In this particular case, it involves a public institution and four independent institutions. The program enables economically disadvantaged students to enroll at the University of Massachusetts - Boston for their first two years of engineering and then transfer to the Electrical Engineering programs at Boston University, Northeastern University, or Tufts University. They may also enter the Electrical Engineering Technology program at Wentworth Institute of Technology. This program seems to be a help to all concerned -- the students, the universities, and industries of the State. This is particularly true because Electrical Engineering graduates are in such great demand by the high technology industries of Massachusetts. The four independent schools are to be commended for their participation in this timely and important project. This project should be continued even if demand decreases, as it is important to monitor the long-term success of this project.

5.2 Community College - University Interface

The Community Colleges are proving to be a very important factor in the flow of engineering students. There is some confusion, however, because the engineering colleges of the state give out different recommendations on curriculum. In some cases, they expect the Community Colleges to rigidly follow the first two years of their own curriculum, even though the first two years are not identical at the various colleges. It seems unrealistic to expect that the three State engineering programs will agree on a common curriculum, but these colleges should be more flexible in accepting students from programs with curriculums that are not in complete conformance with their own. The Community Colleges also expressed the desire that engineering colleges be of more assistance in the professional development of Community College faculty. This could take the form of visiting professoral appointments for periods of a semester or a year, while the Community College professor is on leave from his own institution. Remission of tuition to

Community College faculty taking a course to improve their capability should also be considered. Articulation agreements should be formalized with the various Community Colleges, recognizing that each Community College has different capabilities. Some may only give the math and science required; others may have a few engineering courses, in addition to the math and science; and a few the complete offerings for the first two years of an engineering program, including all mathematics, science, and engineering courses required. To provide greater uniformity, the engineering colleges should consider offering more video-taped engineering courses for the lower level engineering courses. A State-wide effort in this direction would greatly improve the quality of the students transferring from the Community Colleges to the three engineering colleges.

5.3 Educational Delivery Systems

There exist several interesting possibilities for cooperation in the delivery of engineering education.

5.3.1 State Television Network

With the establishment of Massachusetts Corporation for Educational Television, consideration should be given to a cooperative effort by the various engineering schools of the state, both independent and public, of offering graduate course programming. It would be possible to offer courses in a given area by the professor in the state best qualified to give such a course. It could also be used to give a course that would normally have low enrollment to several campuses, as well as many industries, at the same time. The pooling of faculty expertise and the sharing of low-enrollment courses would enhance the quality and provide greater subject matter opportunities for the students. Such collaboration would make the best professional talents and the most distinguished scholars available to serve the graduate engineering educational needs of industry. Use of the state network would permit simultaneous classroom and broadcast delivery to remote sites.

5.3.2 State-wide Video Tape Production

The state engineering colleges should work together on the production of video tape courses. This method would also make the best teachers available to the largest number of students. If the production and distribution of the tapes were centrally handled, it would be less of an economic burden to all concerned. Several of the schools are now making video tapes for their own use, but a cooperative effort would be advantageous to all the schools.

5.4 University - Industry, Government Interface

There are a number of opportunities for cooperation and these should be encouraged by the State through tax relief.

5.4.1 Equipment Donations

While industry in the state has been very active in assisting the colleges, particularly in the computer area, additional help is sorely needed. Equipment donations, therefore, should be strongly encouraged and tax credits should be allowed for such gifts. This should apply to software and maintenance contracts, as well as hardware.

5.4.2 Fellowship Support

Fellowships are of crucial importance to the various engineering schools in offering financial aid to graduate students. Because of the faculty shortage, additional doctorates are needed in all engineering fields. No expansion is possible without a steady flow of qualified doctorates to enter teaching and industry. Support for graduate students is essential.

5.4.3 Joint Research Projects

There is an excellent opportunity to increase the bond between industry and universities by virtue of joint research projects. This would bring timely and important projects to the educational institutions, provide support for students, and provide industries with information pertinent to their missions.

5.4.4 Information Exchange

A cooperative effort is needed at the state level to obtain information on degrees granted, placement of students, and present and future demand for engineers by State industries. Better information is needed to enable the State to do a better job of projecting long-term supply-demand models for the field of engineering.

CHAPTER VI

RECOMMENDATIONS

6.1 Non Institutional Recommendations

6.1.1 High School Mathematics and Science

The Board of Regents should take steps to influence the quality of pre-professional academic training, including strengthening science and mathematics instruction at the secondary school level.

6.1.2 Community College Engineering Transfer Program

Appendix C discusses the community colleges and includes a number of comments and recommendations. It should be understood that there will be a spectrum of programs among the various community colleges. It is specifically recommended that:

- All Community Colleges offer two years of mathematics beginning with calculus, one year of chemistry taught with laboratory, and one year of physics (based on calculus) taught with laboratory. This represents minimal requirements for transfer to an engineering school and students should be informed that approximately three years of additional work will be needed at the engineering school.

- Those community colleges with fairly large engineering transfer programs should offer some engineering courses if it is possible to do so given their available resources to do so. These courses should be designed to integrate into the engineering program at the school selected by most of the engineering transfer students. Such courses should be offered only if qualified faculty are available to teach them and suitable facilities (including equipment) are available. Courses should offered only if quality is high, as the student is ill-served and ill-prepared if the engineering (and science) courses are not of good quality.

- Those community colleges with large numbers of engineering transfer students and with suitable resources should offer the engineering courses normally required in the first two years of an engineering program. These must be high quality offerings, taught by well-qualified faculty with engineering experience. The laboratories associated with the engineering courses should be well equipped. All aspects of the education should be at the same quality level as found at accredited engineering schools. Only Northern Essex and Springfield Technical Community Colleges currently can be placed in this category.

- Individual program reviews completed by the community colleges emphasize the special needs of each program. Those colleges with engineering transfer programs, particulary Northern Essex and Springfield's should be encouraged to include specific requests in their FY'86 budget submissions.

6.1.3 State Colleges

It is recommended that all State Colleges develop strong mathematics and science programs. These programs provide the foundation for further course work in technological fields, and are apropriate to the mission of baccalaureate degree granting institutions. Until such time as Massachusetts can support its existing public colleges of engineering adequately, no state college should be permitted to plan programs in engineering areas.

6.1.4 State Universities

There are a number of common characteristics among the State-supported engineering schools. These are discussed in Appendix A. These comments and recommendations are to be considered as an integral part of this report. Specific recommendations about each of these institutions will be made in part 6.2 of this chapter. Some general comments follow. Praise should be given to the faculty and administrators for their dedication to engineering education at their respective institutions. They are working under difficult conditions due to overloading and lack of resources. Union contracts make it difficult to properly reward faculty for very meritorious performance. Enhancement of engineering faculty salaries is needed to be more competitive with industry and other universities. Equipment is obsolete and inadequate and major appropriation is needed to "catch up" with minimum needs for quality education. Annual appropriations of a greatly increased amount are needed to provide for equipment purchases, so that the colleges can keep up with rapidly changing technology. The Board of Regents should administer these funds to insure that they are spent in engineering and not diverted to other fields.

Additional facilities are needed to overcome the crowded conditions at several schools. Some renovation funds should be immediately appropriated and a study should be initiated to determine the long-term plans for facilities at each institution. New buildings are needed on some campuses, but the planning is not far enough along on the various campuses to commit to a plan at this time.

Additional support staff is needed at both the secretarial and professional technical level. Funds for maintenance of facilities and equipment are also badly needed. On most campuses, computing and library facilities also need upgrading. Specific recommendations for each of the campuses are given in Section 6.2, but some general recommendations are as follows:

- A special fund of $10,500,000 should be set up to be administered by the Board of Regents for the immediate purchase of equipment in the engineering schools. These purchases are detailed in Section 6.2 by specific institution.
- An equipment fund should be set up for the continuing updating of laboratory equipment. A minimum amount of $2,500,000 per year is needed. Details by institution are given in Section 6.2.
- A facilities study should be initiated to determine long-range needs for new buildings, but an immediate allocation of $3,000,000 is needed for renovation of sub-standard space.
- Enhancement of faculty salaries is needed to be competitive with other engineering schools and industry. It is estimated that a minimum of $500,000 is needed for this correction.
- The universities should work with the unions to permit more flexibility, so that performance can be properly rewarded.
- Provisions should be made for adding professional technical staff and secretarial help, as universities are woefully understaffed at the present time.
- Computing facilities and equipment should be upgraded and better access provided for faculty and students.
- Library allocations should be increased to overcome present inadequacies.
- Maintenance funds should be increased to properly take care of equipment.

6.1.5 Independent Universities

The independent institutions are a great resource to the State of Massachusetts and every effort should be made to continue and to increase the cooperation between the independent and public sector insitutions.

- The independent institutions should keep the Board of Regents informed as to their long-range planning. This is particularly important in programmatic areas. The independent institutions should also be kept informed by the Board of Regents of the planning of the state universities. Long-range planning for both sectors will thus be enhanced.

- Independent universities should work more closely with other engineering schools where such cooperation is for the common good. This appears particularly evident in delivery of graduate education programs.

6.1.6 Off-campus Delivery Systems

Graduate engineering education is a very important component of the needs of industry. As such, a cooperative effort of a number of engineering schools may yield far greater benefits than those realized by the institutions acting independently. It is therefore, recommended that:

- There should be established a committee of the leaders of the engineering schools and representative industries to explore this problem and seek possible solutions. Consideration should be given to cross-listing of courses by the various institutions. Such cross-listed courses might be given by video tape or live television. The State television network should be considered as having great potential to help in the delivery of graduate programs. It is obvious that the quality of graduate programs would be improved by having the best teachers and the best delivery systems available.

6.1.7 Tax Incentives

Because of the great needs in engineering education, the State should do everything possible to facilitate gifts by private industry. These may take the form of tax incentives and should cover contributions of money, equipment, software, and maintenance contracts.

6.2 Institutional Recommendations

While the general needs were discussed in the previous section, the needs specific to individual institutions are given in the following section.

6.2.1 University of Massachusetts - Amherst

The Board of Regents should be careful not to let quality at this institution erode. The university's goal is to seek national prominence and the Board should support this. The College proposes to increase the quality of its undergraduate program, but to put major emphasis on graduate study and research programs. This effort should be supported. It appears that the Engineering College has not received an adequate portion of the resources supplied to the campus. Continued monitoring by the Board of Regents is essential to assure the goals of the College are met. Specific recommendations are as follows:

- $4,500,000 should be provided from a fund administered by the Board of Regents for the purchase of equipment needed to catch up with minimum needs. This is detailed in Table 6-1.

Table 6-1
EQUIPMENT NEEDS

	U Mass.-Amherst	Lowell	SMU	Mass Maritime	Total
Average Number of Degrees Awarded					
BS	500	500	175	125	1,300
MS	100	100	10	0	210
PhD	20	0	0	0	20
"Catch-Up Needs"					
BS x $6,00	3,000,000	3,000,000	1,050,000	750,000	7,800,000
MS x $10,000	1,000,000	1,000,000	100,000	0	2,100,000
PhD x $25,000	500,000	100,000	0	0	600,000
Total $	4,500,000	4,100,000	1,150,000	750,000	10,500,000
Annual Equipment Expenditures					
BS x 1,500	750,000	750,000	252,500	187,500	1,940,000
MS x 2,500	250,000	250,000	25,000	0	525,000
PhD x 5,000	100,000	0	0	0	100,000
Total Annual $	1,100,000	1,000,000	277,500	187,500	2,565,000

- Annual equipment allocations for the College should be a minimum of $1,100,000. The basis for this is also given in Table 6-1.
- A detailed study of long-range space needs should be made to determine new building needs. An immediate allocation should be made of $1,500,000 for the renovation of 60,000 square feet of space.
- Additions to faculty (particularly electrical and computer engineering) should be provided.
- Funds are needed to provide for faculty salary enhancement, additional support staff, library and computer up-grading, and better maintenance of equipment.

6.2.2 University of Lowell

The Board of Regents should support the president's efforts to further improve the quality of engineering education. The present historical basis for funding should be reevaluated, as Lowell receives less per student than other public universities that have a proportionately smaller number of engineering students. Specific recommendations follow:

- The overall funding should be improved by correcting the historical base.
- $4,100,000 should be provided from a fund administered by the Board of Regents for the purchase of equipment needed to catch up with minimum needs. This is detailed in Table 6-1.
- Annual equipment allocations for the College should be a minimum of $1,000,000. The basis for this is also given in Table 6-1.
- A detailed study of long-range space needs should be made to determine new building needs. An immediate allocation of $1,500,000 should be made for the renovation of 60,000 square feet of space.
- Additions to the faculty are needed. At the present time, slots are not available.
- Funds are needed to provide for faculty salary enhancement, additional support staff, library and computer up-grading, and better maintenance of equipment.
- Approval should be given to initiate the Doctor of Engineering program in Electrical and Mechanical Engineering. Progress in the program should be monitored and outside reviewers should evaluate progress after two years.

6.2.3 Southeastern Massachusetts University

The Board of Regents should support the institution's increased efforts to supply Master's level engineering education to employed engineers. It is recommended that:

- Authorization for the Ph.D. degree be delayed until the Master of Science in Electrical Engineering degree is truly viable and more mature.
- $1,050,000 should be provided from a fund administered by the Board of Regents for the purchase of equipment needed to catch up with minimum needs. This is detailed in Table 6-1.
- Annual equipment allocation for the College should be a minimum of $277,500. The basis for this is also given in Table 6-1.
- Space needs will be met by a new building presently underway. This will fragment Engineering into several locations. Consideration should be given to a plan that would minimize this fragmentation.
- Some additional faculty are needed, but this has been partially corrected by a redistribution of resources.
- Funds are needed to provide for faculty salary enhancement, additional support staff, library and computer up-grading, and better maintenance of equipment.

6.2.4 Massachusetts Maritime Academy

The Board of Regents should support the continuation of the non-accredited Master of Science in Marine Engineering degree. It is recommended that:

- A contingency plan be developed to include vessel-sharing with other similar institutions and to develop a shore-based facility as a substitute.
- $750,000 should be provided from a fund administered by the Board of Regents for the purchase of equipment needed to catch up with minimum needs. This is detailed in Table 6-1. This equipment is needed for the non-maritime laboratories.
- Annual equipment allocations for the College should be a minimum of $187,500. The basis for this is also given in Table 6-1.
- Additional professional technicians are needed to support the laboratories.

6.2.5 University of Massachusetts - Boston

The Board of Regents should continue to suport the Engineering Collaborative Program, monitoring it for its long-term effect. In addition, it is recommended that:

- The institution should be permitted to initiate the Bachelor of Science in Engineering Physics program, once it has provided evidence of both the demand by industry for its graduates and the interest of students in the program.

6.2.6 Fitchburg State College

The Board of Regents should continue to encourage the improvement of mathematics and science at the college, but it is recommended that:

- Approval not be given for the initiation of either the Bachelor of Science in Electrical Engineering or the Bachelor of Science in Mechanical Engineering degrees.

6.2.7 Salem State College

The Board of Regents should continue to encourage the improvement of mathematics and science at the college, it is recommended that:

- Approval not be given for the initiation of either the Bachelor of Science in Civil Engineering or the Bachelor of Science in Computer Engineering.

6.2.8 Westfield State College

The Board of Regents should continue to encourage the improvement of mathematics and science at the college, it is recommended that:

- Approval not be given for the initiation of either the Bachelor of Science in Microcomputer Applications Engineering or the Bachelor of Science in Microelectronics Engineering.

6.2.9 Roxbury Community College

The Board of Regents should support the upgrading of mathematics and science and the institution's goal toward offering courses applicable to the first two years of engineering. It is recommended that:

- The College should offer two full years of mathematics, beginning with calculus, one year of chemistry taught with laboratory, and one year of physics (based on calculus) taught with laboratory.

- Funds should be provided to adequately staff the above.
- Funds should be provided for adequate laboratories associated with the science courses.

Appendices

Appendix A	Reports - Public Institutions
Appendix B	Reports - Independent Institutions
Appendix C	Reports - Community Colleges
Appendix D	Massachusetts Statistics
Appendix E	Regents Statement - Manpower

Appendix A

Reports - Public Institutions

GENERAL RECOMMENDATIONS ON
ENGINEERING EDUCATION IN THE PUBLICLY-
SUPPORTED INSTITUTIONS OF MASSACHUSETTS

1. During a time when engineering is a popular career choice of university students, when faculties of existing programs are hard-pressed to cope with overcrowded classes, and when there are predictions of a shortfall in some disciplines of engineering manpower for industry important to the economy of Massachusetts, there is a tendency by some to view the creation of new engineering schools as the answer to these problems. It is recommended strongly that the Regents resist this approach as being unsound both economically and educationally.

What most proponents of the "create a new school of engineering" approach fail to understand is that aside from the very substantial first-cost of creating a new engineering program (for which qualified faculty are in very short supply), the maintenance of truly high-quality engineering education is equally as expensive as good medical education. Massachusetts does not need new engineering colleges—it does need to do a better job of supporting the ones it has. Given the resources to do so, the existing programs are perfectly capable of supplying, in concert with the private institutions, the needs of the Commonwealth for quality engineering manpower.

2. Equipment for undergraduate teaching laboratories in engineering is subject to rapid obsolescence and is very expensive. The state has not done a good job of providing the resources necessary to keep those laboratories reasonably up-to-date with the result that most are in dire need of equipment replacement. It is recommended that a more realistic equipment budget be developed by the Regents for the four institutions in question to address this special need. There is no nationally-accepted figure on the level of expen-

diture required for quality laboratory instruction, but studies by individual institutions and consortia of universities have produced estimated annual equipment replacement needs. One such study suggests the need for an expenditure of $1,500/year per BS graduate to keep engineering labs current. It is probably not reasonable to assume that the state will increase its funding for instructional laboratory equipment in engineering to that level in the short term. What does appear reasonable, though, and it is recommended that the Regents consider this approach, is a budget which includes engineering equipment funds at about one-third to one-half this level in addition to current equipment funds received by the universities, coupled with the expectation that the institutions make better use of the funds now allocated for equipment and that the engineering colleges continue and expand their efforts to attract equipment gifts from the private sector.

3. Engineering undergraduate enrollments have more than doubled nationally over the past decade, while the number of faculty positions has only increased about 12 percent. Roughly 3 percent of the authorized positions are unfilled for lack of qualified applicants. The result of this disparity in growth of student body and faculty is severe overcrowding of engineering classrooms, and Massachusetts is no exception to this national phenomenon. There is need for additional engineering faculty lines in the budgets of each of the institutions with the exception of the Maritime Academy. The need is not uniformly spread across the engineering disciplines, however, so each discipline should be required to document its degree of overcrowding and its need for more faculty to maintain quality. As noted elsewhere, the institutions have differing degrees of difficulty in attracting faculty, so the overload problem will not necessarily be solved immediately with allocation of new positions. Reports were received by the visiting team of some difficulties in recruiting

due to lack of a firm commitment that a position was available until well into the recruiting process. Whether this is a local situation or one which occurs statewide was not clear but in any event any additional obstacles in an already difficult recruiting situation should be removed.

4. During the past fifteen years the number of accredited engineering schools in the nation has increased from roughly 150 to 250, and the number of new doctoral programs has grown at almost the same pace. Some of the graduate programs are doing well, many are still struggling to get the resources and the student population required to mount a viable program. It is against this backdrop that the suggestions are made in the text regarding the two proposals for new engineering doctoral programs.

In the SMU case, the suggestion is that a more active and productive MS program be developed before the PhD proposal is pursued. For the Lowell proposal, it is suggested that the decision-making process be rooted in impartial academic, financial and demand analyses. And whatever the decision regarding new programs, it should be remembered that UMass - Amherst has relatively mature PhD programs in engineering, some of which if properly nurtured have the potential for national prominance.

SOUTHEASTERN MASSACHUSETTS UNIVERSITY

Engineering students account for approximately twenty percent of the enrollment at SMU. The engineering programs are an integrated combination of engineering and engineering technology offered by a common faculty.

Engineering and Engineering Technology Programs

The BS degree is offered in five engineering disciplines—civil, electrical, mechanical, computer and construction engineering. The latter two are relatively recent additions and are offered by the same faculties respectively as electrical and civil engineering.

Four-year programs leading to the BS degree are offered in electronic engineering technology and mechanical engineering technology. As noted earlier these are offered by the faculties of electrical and mechanical engineering.

The combined enrollment in engineering and engineering technology is approximately 1,200 students, with engineering accounting for about two-thirds of these. Combined BS degree production during the past year was 199.

At the graduate level only one degree is offered, the MS in Electrical Engineering. There are currently 30-40 students enrolled in the program, of whom ten are full-time. Six MS degrees were granted in 1982-83.

Supporting Services

Staff: The 39 faculty members in the College of engineering have three secretaries, with the faculty of Electrical and Computer Engineering alone having one secretary for 17 faculty. Technician help is in equally short supply with three technicians to take care of the equipment repair and installation for laboratories and computer facilities for the entire College. Some relief has been effected for the overloaded faculty by providing teaching assistants for grading help using funds made available by a $40/student laboratory fee.

Library: SMU is still in the stage of developing a full-scale university library from the combined libraries of the two predecessor institutions. To move from a technical institute collection to one which can serve the needs of an engineering school requiring upper-level and graduate resources requires, in addition to the usual formula funding for an established library, a period of special funding which the SMU library has not received. The institution supplemented its library budget internally this year by taking $30,000 from the supply budget.

Computers: Computer service and facilities at SMU are not yet adequate for the engineering programs. The situation could be improved considerably if approximately 100 terminals and a VAX 780, delivered some six months ago, would be installed and put into service without further delay. It will be difficult for the University to recruit qualified faculty into an atmosphere of inadequate computer services.

Perceived Strengths and Weaknesses

Strengths of the engineering programs include (1) a modern physical plant, (2) the move by current central administration to effect some reallocation of resources, (3) some improvement in allocation for instructional laboratory equipment during past two years, although not sufficient to meet critical needs, (4) good integration of engineering and engineering technology programs with a faculty under single management, (5) present efforts to improve industrial ties and strengthen the MS program, (6) good laboratory space, and retention in the face of enrollment pressures of a viable laboratory squad size for effective learning, (7) strong commitment of the faculty to classroom teaching.

Some areas of concern are: (1) no merit salary money available in the salary budget to reward outstanding performance, (2) heavily loaded faculty resulting in excessively large classes at the upper division level in several disciplines, (3) difficulty in attracting qualified faculty, although beginning salaries are competitive, (4) some use of promotion to effect salary increase, (5) reported decrease in quality of entering freshman class in the fall of 1983, (6) lack of installation by University of computer facilities which were delivered in the summer of 1983.

Program Directions

Present plans both at the College and University levels are for special emphasis in Electrical and Computer Engineering to match the principal industrial focus of the region and the Commonwealth. Good efforts are currently underway to create stronger ties with the industry of the region to increase participation in the MS program offered by Electrical and Computer Engineering, the only graduate program in the College. The College has also proposed that this department be authorized to offer the PhD degree.

Also in the plans of the College of Engineering are continued efforts to improve funding for instructional equipment and for additional faculty positions to bring teaching loads to a level consistent with quality education. And the College anticipates relief from overcrowding in some disciplines through the acquisition of space in a new classroom building to be constructed.

Comments on Plans:

The proposed emphasis on electrical and computer engineering appears appropriate in the present climate. There is considerable potential for growth of the MS program as a service to industry in the surrounding area, and current efforts to expand relations with that industry should be continued.

With regard to the proposal for the PhD degree, it is the opinion of the visiting team that such a move is premature and that further consideration of the proposal should be delayed until it can be demonstrated that there is capacity and demand for a truly viable MS program. This recommendation is not predicated on whether the faculty in the Department of Electrical and Computer Engineering has the numbers and the level of experience in research and scholarship to offer the PhD. We assume that common practice would be followed of bringing in a team of experts in the discipline to judge the capabilities of the primary and supporting departments to offer the degree. Rather, the recommendation reflects the fact that the College is struggling under very difficult funding and staffing conditions to maintain the quality of its undergraduate programs and its single MS program, making an excursion into PhD production at this time appear ill-advised.

The administration of the University is to be commended for recent efforts to preserve the equipment budget by reducing its use for part-time faculty, and for its plans to reallocate positions made available through attrition. These have helped the College of Engineering address in part the problems of obsolete equipment and inadequate faculty numbers, but the current University budget for these items does not make possible a totally internal solution to the problems which will allow the College to preserve the quality of engineering and engineering technology education.

UNIVERSITY OF LOWELL

The University of Lowell offers a broad array of engineering programs at the BS and MS level plus evening programs leading to the BS in engineering technology in several disciplines.

Engineering and Engineering Technology Programs

The BS degree is offered in chemical, civil, electrical, mechanical, nuclear and plastics engineering plus an option in paper engineering within chemical engineering. Enrollment in these programs is approximately 3,000, and 455 BS degrees were conferred in 1982-83.

Nine programs are offered leading to the MS in Engineering. These are in chemical, civil, computer, electrical, mechanical, energy, paper, systems and plastics engineering. These programs enroll about 300 FTE students and granted 94 MS degrees during the past academic year.

Engineering technology BS degrees are offered in civil, electronic, and mechanical technology, all in the evening for the benefit of local industry, and employing a separate faculty. Two-year Associate degrees are also offered in these disciplines with the curricula designed for easy 2 + 2 transition from the two-year to the four-year program. These programs have about 1,000 students enrolled and granted 45 BS and 34 AS degrees in 1982-83.

Supporting Services

· Staff: While technician support in the College appears to be adequate, the allocation of one secretary per department has resulted in service which varies from marginal in the smaller departments to totally inadequate in larger ones. For example, a department with 23 faculty and well over 1,000 students is obviously in need of more than one secretary.

The situation improved markedly during the past year with regard to teaching assistants who can help the faculty with grading of homework in the overcrowded classes. The University allocated $200,000 of income from continuing education programs to Engineering to allow hiring of a substantial number of teaching assistants.

Library: The library is staffed by competent professional personnel who understand the needs of engineering and engineering technology. Close liaison with the engineering units is maintained by the Director of the library.

The budget for the library is insufficient to allow it to meet the needs of Engineering which result from expanding programs, rapidly changing technology and escalating costs of technical books and periodicals. Coupled with this general problem has been another caused by delay in allocation of the library budget which results in delay of acquisition of those materials which can be added.

The University is commended for the public service activity of the library. Continuing expansion of the "corporate members" group should provide additional revenue and strengthen further the ties with the industrial community.

Computers: Computing services at Lowell are good and have the potential of becoming excellent. The "networking" which is underway will greatly benefit students and faculty. Plans to provide each faculty member with a terminal in the faculty office will make available excellent computing power at the local level and should result in improved integration of computer utilization throughout the educational program.

Computer center personnel are understanding of the needs of engineering and are making excellent progress in meeting those needs. Innovative financing has been developed, and plans are underway to seek federal support for further improvement of computing services. Special attention has been given to the use of computer facilities in teaching design methodology to all entering engineering students.

Perceived Strengths and Weaknesses

Strengths of the engineering programs include: (1) capable and aggressive university leadership which is taking advantage of the unique location of the University in an area of high concentration of industry, (2) creative solution of laboratory equipment problems through industrial gifts and engineering student fees, (3) enthusiasm of most faculty for new directions being pursued, (4) acquisition and effective utilization of excellent computer facilities, (5) incentives for faculty research through substantial overhead return and salary enhancement, (6) provision, through income from continuing education programs, of teaching assistants to provide some relief for heavily loaded faculty.

Some areas of concern are: (1) continued overload of the faculty, (2) limited capability to award merit increase in salary, (3) lack of movement by faculty in some departments to adapt to changes in disciplinary priorities, student interest, industrial needs, etc., (4) lack of funding base for the University commensurate with an enrollment which is 40% engineering.

Program Directions

The College of Engineering has two major thrusts which it is pursuing. One is a proposal to offer the Doctor of Engineering degree with a major in any of the current degree-granting engineering disciplines. The other is an effort to improve the funding for the College to allow the hiring of additional faculty (to prevent further deterioration of the quality of present programs) and to provide a stable equipment replacement and maintenance budget to complement the work that has been done to acquire equipment through industrial gifts and student fees.

Comments on Plans:

The Doctor of Engineering proposal has the advantage of enthusiastic support by the faculty and of endorsement by several key people in local industry who were queried by the President regarding the idea. The general approach of providing the engineering doctoral candidate with a research experience which is much more applied than that of the physical scientist is of course not new. Several engineering schools have taken this orientation through the DEng degree, and many more either require or make such a research project possible under the PhD degree. So the question is not whether such a degree is a reasonable idea but rather whether the proposal is a viable one in terms of the quality of the program, financial resources and student interest.

Several actions are recommended for the Regents and the University which may slow down the decision process on the proposal a bit but which would put it on much firmer ground than it now appears to be. First, with regard to quality of the degree, the usual approach by a university in proposing a new doctoral degree is to satisfy itself (and the state or trustees) that it has the faculty with appropriate experience and credentials, the facilities and the financial and administrative support to offer the degree. This is usually done by bringing in some recognized experts in the discipline in question to give an independent judgment. In the case of the Lowell proposal such a process has not been followed. The proposed program would authorize any one of the disciplines in the College to grant the DEng, so it seems even more important that some independent assessment be made of the readiness of each to offer the degree.

Second, with regard to financial resources for the proposed DEng program, it should be determined that the incremental costs are understood and will be met by the Commonwealth before the program is authorized. Engineering education at Lowell is very much underfunded now, and the addition of an underfunded doctoral program would not bring credit to the University or the state.

Finally, it does not appear that good market research has been done on the potential demand for the program. It is designed to serve primarily the full-time resident student, and except for the most prestigious institutions, engineering schools across the nation are having difficulty attracting enough (especially, US national) students to mount a viable graduate program. Lowell is, of course, in a favored location with respect to industry, but it is not clear that this would produce an influx of DEng students. It would be useful for the Regents and the University to investigate the experience of Northeastern University, which offers the DEng under a somewhat different format from that proposed, to see if any inferences can be drawn about student demand for the proposed program at Lowell.

Turning to the other major thrust of the College, improved funding for present programs, this complements efforts by the President to secure more equitable funding per student for Lowell. The University has an enrollment composed of 40 percent engineering students compared to 20 percent and 10 percent respectively at SMU and UMass - Amherst. Given the fact that quality engineering education is more expensive than most other undergraduate education (and in fact is funded differently in the formula budget of most states), there is no doubt about the need for improved funding at Lowell even if the Engineering College were not facing its current serious problems of maintaining quality.

UNIVERSITY OF MASSACHUSETTS - AMHERST

Engineering education at UMass - Amherst is the most mature (excluding engineering technology) of that found in the publicly-supported universities. Even so, it has a relatively recent history, 35 years, compared to that of many other public and private institutions in the state and region.

Engineering Programs

The university offers the BS degree in five basic engineering disciplines—chemical, civil, electrical and computer, industrial and mechanical—and had 2,372 undergraduate engineering students enrolled in the fall term of the 1983-84 academic year. BS degrees granted in 1982-83 numbered 512.

The College of Engineering offers a full range of graduate degrees, MS and PhD, in these five disciplines, plus the MS degree in engineering management and in manufacturing engineering and the MS and PhD in environmental engineering. Current graduate student enrollment is 524, and the University granted 101 MS and 13 PhD degrees in 1982-83.

Research activity by the faculty and graduate students as measured in terms of dollar volume of contracts and grants is moderate but has increased by roughly one-third during the past two years.

Supporting Services

Staff: Support staff for faculty in the engineering departments is extremely limited, particularly in view of the heavy enrollments and consequent faculty overload in most departments. Secretaries, technicians and teaching assistants are in short supply. Secretarial and teaching assistant staff is roughly the same as that found when enrollment was half the current figure.

Library: The physical science and engineering library has a professional staff which understands the needs of the engineering disciplines and gives appropriate priority to their requests within the constraints of available funds. The budget is not adequate for the needs of engineering but the staff has been able to provide reasonable service through the use of interlibrary loan systems. The lack of a consistent budget, even if insufficient in amount, has been a severe handicap in planning for library holdings. Although engineering enrollments have doubled over the past decade and graduate study and research has gone up substantially, all increasing engineering use of the library, the size of the library staff has remained constant during that period.

Computer: Computer services and facilities are good and improving. Evidence of good planning for the future appears university-wide and in the College of Engineering. Computer expenditures per student appear to provide reasonably good support throughout the University, although there were reports of queuing problems for use of the computer in undergraduate instruction in some engineering departments.

The expansion of CAD/CAM instruction in engineering with the acquisition of the IBM gift equipment is a very positive asset. Maintenance and operational costs for this equipment will of course place an added burden on the meager equipment budget of the College. Of special note are the cooperative attitudes of the Director of the Computer Center toward engineering and the experiments with computer-aided instruction in the College.

Perceived Strengths and Weaknesses

Strengths of the engineering programs include (1) a competent and dedicated faculty, (2) the thrust of the College leadership to improve the position of Engineering in research and graduate study, (3) high ranking nationally for rapid improvement in four disciplines in recent NAS-NAE rating of graduate programs, (4) ability to attract well-qualified faculty, (5) success of capital fund drive in attracting major computing equipment gifts, (6) negotiation of agreement for purchase of personal computers for use of majority of faculty, (7) availability of Regents doctoral fellowships, (8) development of video-tape delivery of engineering courses for off-campus instruction.

Some areas of concern are: (1) An instructional laboratory equipment budget which is totally inadequate for current replacement and maintenance, not to mention catching up with a $3 million shortfall due to obsolescence, (2) shortage of space, and of quality of the space, for instructional laboratories, (3) severe overloading of faculty in several disciplines, exacerbated by the lack of account of research time in calculation of student/faculty ratio mandated by union contract, (4) lack of opportunity for appreciable merit reward for outstanding work by faculty, (5) poor morale among some faculty, and particularly among some junior members, due to workload and perceived lack of attempt by central administration to effect reallocation of resources, (6) lack of stability in leadership positions of university, (7) lack of good followup and contact with graduates.

Program Directions

Among plans for future directions of the College are: (1) improvement in quality of undergraduate instruction, (2) some modernization of undergraduate instructional laboratory equipment through imposition of a special fee for engineering students, (3) reduction in teaching loads to account for differences in undergraduate and graduate instruction, research activity and class size, (4) substantial increase in research activity of faculty with accompanying increase in dollar volume of research, PhD production and ratio of graduate to undergraduate students (5) integration of computer utilization throughout curriculum of each engineering discipline.

Comments on Plans:

The stated objectives of the College appear to be attainable over time given adequate administrative and financial support. A potential roadblock in the goal of increasing faculty involvement in research is the lack of a clearly-defined method for taking research activity into account as a part of the teaching load. The Massachusetts higher education system commendably assumes that research is an integral part of the academic year workload with the result that it has not been the practice, in contrast to the situation in most other states, for the faculty member to request salary (except for the summer) in proposals for research support. The absence of an appreciable amount of merit pay increase money as a part of the collective bargaining agreement is another factor which inhibits the extra effort which must be devoted to the development of a research program. The Applied Technology Center with its generous overhead return to the researcher plus the opportunity for salary enhancement may prove to be a useful medium for encouraging industrial research, but it has not yet involved a substantial fraction of the faculty. It is possible, of course, that given the rewards of rank, tenure, peer acceptance and personal satisfaction, most professionals of the calibre found in the UMass faculty will do research anyway, but it would obviously make the task easier if some disincentives could be removed.

The goals expressed by the leadership of the College of Engineering are not reflected specifically in the plans of the University, either in written or oral form. While it may be that this simply indicates the timing of the visit by the team during a period when plans were in the making, it is obvious that the directions for the future envisioned by the College are only meaningful as they mesh with the overall plans and priorities of the University. The plans of the college for a considerably expanded effort in graduate studies and research will of course require additional resources. There is potential in the College for attaining a position among the leaders of state-supported schools of engineering in the nation, but to achieve that goal will require a positive commitment by the University and by the Commonwealth that this goal will receive the necessary administrative and financial support. It does not appear that the College has developed as a part of its current five-year plan an assessment of the incremental cost to the Commonwealth of the proposed move to a heavier involvement in graduate education. This would, of course, be a necessary prerequisite to agreement by the University administration and by the Regents to give this thrust by Engineering a priority position.

Quite apart from the decision to support a move by the College to national prominence is the need to insure that the quality of the current educational programs is not eroded. The College is at a crossroads and can either go forward or backward. The proposed student fee should be approved as a partial solution to the laboratory equipment problem. A budget for undergraduate laboratory equipment which has been neither adequate nor consistent for many years has produced a deplorable situation in those laboratories. This problem is coupled with the reward system and the current excessive teaching loads in several disciplines, not necessarily in credit hours but rather in student contacts, with the result that some competent younger faculty members are becoming discouraged and looking elsewhere.

MASSACHUSETTS MARITIME ACADEMY

The Massachusetts Maritime Academy is a very specialized member of the publicly-supported institutions offering engineering education in Massachusetts. The Academy grew out of the Massachusetts Nautical Training School established in 1891 and in 1964 became a member of the Massachusetts State College System. The stated purpose of the institution is to educate young people for professional careers at sea. Bachelor of Science Degrees are offered in Marine Engineering and Marine Transportation.

Marine Engineering Program

The 250 students who are admitted to the Academy each year are undeclared during the freshman year as to which of the two available programs will be pursued. In recent times, about two-thirds of them chose the marine engineering program, and 112 degrees were conferred in the discipline in 1982-83.

The Marine Engineering program is a rigorous four-year program which contains a heavy concentration of courses designed to prepare the graduate for the special responsibilities of an engineering officer aboard a modern ship. The program is not accredited by the Accrediting Board for Engineering and Technology, nor has engineering accreditation been sought, but the Academy is accredited by the New England Association of Schools and Colleges.

The marine engineering faculty has been increased by 25 percent over the past three years and now numbers twenty. All of the new faculty additions hold the Advanced Marine Engineering License, and over half of the faculty hold either a Chief Engineers' License or the PhD degree. The curriculum has been altered significantly over the past few years to adapt it to the technological changes found in the modern merchant marine fleet. Excellent new computer-controlled simulation facilities have been added for student training in ship handling and engineering.

A special feature of the program is the requirement of 130 days of sea time for each student. To accomplish this, the Academy takes about two-thirds of the student body on a 60-day training cruise each year, although many of the students satisfy part of the requirement by shipping out on a commercial vessel.

Supporting Services

Staff: Secretarial support for the faculty appears to be adequate, but there is only one technician available for maintenance and installation of laboratory equipment. Beside the standard laboratory equipment required for undergraduate engineering courses, the Academy has much specialized equipment appropriate to its mission of educating marine engineers, and there is no technician support available for some of this highly sophisticated equipment.

No teaching assistants are available, but this does not appear to be a problem. The enrollment is limited and allows for a manageable size for both lecture and laboratory classes.

Library: Given the limited number of programs and the size of the faculty and student body, the library resources of the Academy are reasonably good. The budget will not allow acquisition of all the books and periodicals which might be desired, but a good interlibrary loan system is in effect which makes almost any material available on request.

Computers: Computer facilities appear to be adequate for current computer use required of students. Since both students and faculty were at sea on the annual cruise at the time of the team's visit, it was difficult to determine the extent to which students are required to make use of the computer. One would expect, however, that if use of the machine as a problem-solving tool were integrated throughout the curriculum of the marine engineering program, the current number of terminals would not be sufficient.

Perceived Strengths and Weaknesses

Strengths of the marine engineering program include: (1) a strong faculty with good academic and professional qualification for this specialized program, (2) excellent physical facilities, (3) a highly-motivated student body, (4) good leadership which has moved the program to stay abreast of applications of sophisticated technology in the shipping industry, (5) some excellent laboratories which simulate actual navigational and engineering conditions aboard ship.

Areas of concern are: (1) the lack until very recently of a training vessel for the required cruises and for use as a working laboratory when docked, and (2) insufficient budget for instructional laboratory equipment outside the specialized marine equipment areas and for proper maintenance of all laboratory equipment.

Program Directions

The major concern of the Academy administration during the recent past has been the acquisition of a training vessel. At the time of the visit by the team, a ship had just been purchased with funds appropriated by Congress to the Maritime Administration. The vessel is a compromise with what would be desirable, since it does not have a modern low-speed diesel power plant. The estimated cost of conversion of the ship from its present configuration to that of a training vessel is $11 million. Only $6 million is presently available, so the acquisition of a training vessel continues to be a challenge.

For many years graduates of the Academy were placed immediately upon graduation in jobs for which they were trained. The situation has changed with the downturn in the shipping industry. Jobs for graduates are not nearly so available, although the placement record of the institution is still very good. The Academy has received suggestions from various sources that it alter the engineering program to offer an accredited mechanical engineering degree to give the graduates more job options. Some thought has been given to such a change by the administration, although no decision has yet been made to take this step.

Comments on Plans:

A training ship serves the dual purpose of providing the required seatime for the students and of being used as a full-scale working laboratory while it is docked at the Academy. As the degree programs are now structured, this is a very central requirement for the institution, and the plan to renovate the recently purchased ship for service as a training vessel should be a top priority. There are, however, signs that the Maritime Administration and the states involved may not continue in the long run to provide the considerable purchase and maintenance costs required for each of the major maritime academies to have its own full-time training ship. The Academy might therefore be developing a long-range contingency plan to include sharing of a vessel with other institutions coupled with the development of creative large-scale shore-based laboratories.

With regard to the possibility of altering the marine engineering program to provide opportunity for some or all students to graduate from an accredited mechanical engineering program, such a move seems ill-advised. If a student wants a degree in mechanical engineering, he or she should go to one of the several institutions currently offering that degree in the Commonwealth. To change the marine engineering program to an ABET-accredited one in mechanical engineering would produce a considerable change in its character. The Massachusetts Maritime Academy has a very specialized mission, and it performs that mission extremely well. The Commonwealth will be best served if the institution continues on its present course.

Appendix B

Reports - Independent Institutions

BOSTON UNIVERSITY

Boston University has embarked on a $80 million program to provide new buildings and facilities for engineering and the sciences. Enrollments in engineering hit a low in 1973, when its enrollment fell to 162 full-time-equivalent students. In 1983-84 enrollment of undergraduate engineering students had increased to over 2000 students. The College of Engineering has made a major effort to attract high quality students and the average mathematics SAT scores of its students are the highest of any college at Boston University. The college has also been effective in recruiting women and minority students into their engineering program. The faculty has tripled in size since its low point in the mid-seventies.

Approximately 70% of the engineering students come from New England, and approximately 40% come from Massachusetts. The college has a number of 3 + 2 programs and works most effectively with the University of Massachusetts at Boston in accepting Electrical Engineering students from within the Collaborative Program of that institution.

Boston University offers BS programs in 7 disciplines of engineering and the MS in 5 disciplines and the Master of Engineering in Manufacturing Engineering. The PhD program was initiated a year ago.

Emphasis is being placed on distinctive programs (versus traditional) in such fields as biomedical, computer, microelectronics, manufacturing and aerospace engineering. Off-campus graduate courses are also offered to engineers in industry. Graduate course offerings are now sufficient in number to permit graduate students to work full time toward the MS degree.

Boston University is the only school that had major plans for expansion

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

MIT is universally recognized as one of the outstanding engineering schools of the world. It is a great asset to the Commonwealth of Massachusetts. Many of its students remain in Massachusetts upon completion of their degrees. President Paul Gray cited the Electrical Engineering and Computer Science students to illustrate this point. Although only 10% of these students come from Massachusetts, approximately 40% remain in the state, taking positions in Massachusetts industries. Of some 70,000 MIT alumni, 15,000 live in Massachusetts with approximately 11,000 in the Boston area. A large number of high technology companies have been started by MIT graduates or otherwise spun off from research activities at MIT.

MIT offers ABET-accredited Bachelor of Science degrees in ten different engineering disciplines, the Masters of Science in nineteen engineering or engineering-related disciplines the degree of Engineering in several fields, and both the Doctor of Science and the Doctor of Philosophy degrees.

An internship program has also been established for a limited number of students who are chosen at the end of their sophomore year. It is a five year program resulting in both the BS and MS degrees. The student spends two summers after his or her sophomore and junior years with the company. During the senior year he or she goes with the company for a summer and a semester and returns to MIT for a final semester. The thesis is usually done at the company.

Several other industry cooperative educational programs are offered. Jointly with the Sloan School of Management, the Engineering School offers a Masters degree in the Management of Technology for engineer-managers with several years of experience.

MIT has a number of centers and laboratories which undertake focused interdisciplinary and/or major targeted areas of research. Many of these units derive a substantial fraction of their research support from industry. Total estimated engineering research from contracts and grants was about $53 million in 1982-83.

MIT is very cognizant of its responsibilities to society as a leading institution of its kind. It is very actively working with industries and has offered a number of different programs for engineers already in industry. These include non-degree programs, as well as videotape courses that may be purchased or rented. Close liaison with industry is also maintained by the various centers and laboratories. The School of Engineering also participates in the MIT Program in Science, Technology and Society and has several activities related to technology and public policy.

An administrative staff of 56 and a faculty of approximately 373 handle these programs. In Fall 1983, there were 2418 undergraduates and 2191 regular graduate students enrolled in the School of Engineering.

MIT has long been considered a source of innovation in engineering education.

MERRIMACK COLLEGE

Merrimack College began a Civil Engineering degree program in 1951 and Electrical Engineering was added in 1954. The financial condition of the institution is sound and there is a five year plan to remove all debt. The institution has operated at a deficit for several years but now has the operating budget in balance. Ninety-five percent of the operating budget comes from tuition.

The institution has 2100 day students including co-op students (approximately 125 co-op studients are on off-campus assignment at any one time.) Approximately 200 students are enrolled in engineering programs. Of the 1400 students attending night school courses, approximately 150 are enrolled in engineering courses. Most of the students come from Massachusetts and the rest from New England. Most of the engineering graduates stay in the immediate area (eastern Massachusetts).

Merrimack College expects to stay small but puts its efforts toward improvement in quality. It hopes to attract some support from industry in this effort.

The capital equipment budget is very small and, as a result, the equipment needs are great, especially with respect to large equipment items. The faculty is small in size but very dedicated to its mission. Some consideration has been given to adding a Mechanical Engineering program, but this has not progressed beyond the discussion stage.

Although the Catholic high schools are feeder schools to the Merrimack program, about 60 percent of their students come from public high schools. A study is now in progress concerning space and needs. It is hoped this will alleviate the shortage of space in both Electrical and Civil Engineering.

Merrimack College hopes to be a distinctive institution, i.e. a relatively small Catholic college with an integration of the liberal arts into all of its programs.

NORTHEASTERN UNIVERSITY

Northeastern University has had a long and distinguished history of providing educational opportunities to students working part-time or full-time while pursuing an education. Its cooperative program at the undergraduate level has been nationally recognized for many years. It has had a large evening program in engineering at the MS level. A small on-campus doctoral program also is offered.

There are approximately 4200 undergraduates in B. S. engineering programs, with more than 1000 in the Electrical Engineering program. About 15% of the undergraduates are part time students in the evening program. During the economic downturn it was difficult to place co-op students in jobs in industry. About 88% of students were so placed, with particular difficulty being noticed in placing foreign students. Most students stay with the same employer for their co-op experience and about 60% are offered employment with that employer upon completion of the B. S. degree. About 40% of the students end up going to work upon graduation with their co-op employer. Students are accepted from the University of Massachusetts at Boston collaborative program and this seems to be working well. Some students enter after taking some of their course work at community colleges.

TUFTS UNIVERSITY

Tufts University has a relatively small engineering college with degree programs through the doctorate in the four principal engineering disciplines. The school attracts extremely high quality applicants whose Mathematics S.A.T. scores average about 700. There has been a shift in the enrollment in the various departments with a great increase in the number of students in Electrical Engineering. EE enrollment has more than doubled in the last five years and now numbers more than 100 in each of the sophomore, junior and senior classes. There are only eight faculty members in the Electrical Engineering Department and, hence, teaching loads in that department are very high.

Tufts has a fund drive for $140,000,000 with $10,000,000 allocated for engineering. Planning calls for a center of excellence in each department, Civil Engineering - environment studies; Chemical Engineering - bio-engineering; Electrical Engineering - electro-optics, and Engineering Design - CAD-CAM. The PhD programs will be developed and emphasized in these areas of strength.

Tufts participates in the collaborative program with the University of Massachusetts - Boston and has taken two students to date from that program.

WENTWORTH INSTITUTE OF TECHNOLOGY

Wentworth Institute of Technology is a private four-year technical institute originally chartered in 1904. Current enrollment in 2 and 4 year engineering technology and related programs includes 3,384 FTE day, 1,000 evening students and 360 week-end students. Total yearly graduates include 350 baccalaureate and 650 two-year graduates. Four colleges are organized for Arts and Science, Aeronautics, Engineering Technology and Design & Construction. Completion credentials include a Bachelor of Science in Engineering Technology, Associate in Engineering, Associate in Applied Science, and Certificate of Graduation. Planning for the future includes consideration of a five year Bachelor of Architecture degree and a Master of Science degree in Technology, and planned expansion to a total enrollment of 5,000 in five years.

Unique arrangements and articulation agreements have been developed with selected high schools, community colleges, colleges of engineering and universities. A number of public and private institutions are involved and include formal agreements including transfer arrangements and planning for extension of the weekend college to other institutions. One example is the unique cooperative academic arrangement with Emmanuel providing graduates with both a teaching certificate in technology and the bachelor's degree from Wentworth.

Close contacts with industry are provided by the members of the non-stock, non-profit corporation and by the various Industrial Professional Advisory Committees. Academic programs are offered at various industries in Massachusetts and other states. International activities include both advisory and evaluation activities in Saudi Arabia as well as contract activities in offering academic programs. Current facilities available at Wentworth provide for easy expansion of additional programs and academic activities. There is a two-way flow of students transferring between Wentworth, the community colleges, engineering colleges and other state and private institutions in engineering technology.

WESTERN NEW ENGLAND COLLEGE

Western New England College started in 1919 (as part of Northeastern University). Enrollment in engineering bottomed out in 1972 with 270 students enrolled. Enrollments have more than doubled and are now at 590. About 60% of the students come from Massachusetts. The institution has always operated in the black although 95% of the operating budget comes from tuition income. Outside funds have been solicited for capital only (never for operating funds). Present endowment is about $3.2 million Total full-time undergraduate enrollment at the institution is being capped at approximately 2000 with about 25% of the student body enrolled in engineering.

Concern was expressed about the coming drop in 18-year-olds in Massachusetts and its effect on enrollments. This is of particular concern because the budget is primarily tuition (enrollment) driven.

Western New England is one of eight colleges in the Springfield consortium, which provides joint library access, some joint purchasing and some cross registration.

Western New England offers BS degrees in 5 fields of engineering and MS degrees in Electrical Engineering and Engineering Management.

WORCESTER POLYTECHNIC INSTITUTE

Worcester Polytechnic Institute (WPI) has a long history in engineering education. It has a reputation for innovation in engineering instruction. WPI offers BS, MS and PhD degree programs, with departments of CE, ChE, EE and ME. There are 73 faculty members in these departments. There are about 1950 undergraduate engineering students with about 430 receiving B.S. degrees annually. Sixty to seventy MS degrees and several PhD degrees are also awarded annually in engineering. The MS program has approximately 125 full-time engineering students in the day program and 275 part-time in the evening program. In addition to the departmental programs there are also graduate level programs in Biomedical Engineering and Fire Protection Engineering, with 23 full-time students in the former, with 10 in the latter and 31 part-time evening graduate students in Firesafety.

WPI also has a Computer Science Department (closely related to engineering) which has 13 full-time faculty members and which offers B.S., M.S., and PH.D. degrees. There are 256 undergraduate majors, 31 full-time day graduate students, and 275 part-time masters students enrolled in the evening program.

Over 50% of the students are from Massachusetts. 80% of the entering students are from the top 20% of their high school classes. More than 75% of the admitted students have mathematics SAT scores in excess of 600. Although a 40% drop in the number of 18-year-olds is expected by 1990, WPI expects to expand its applicant pool, principally by attracting a higher percentage of women and minority students.

WPI has received national attention with its innovative approach to undergraduate engineering education. All students are required to complete at least one major engineering project before graduation. Other required projects must include some emphasis on societal problems. The academic year is divided into 4 seven-week sessions. The project approach is very demanding on faculty time but does provide excellent student-teacher interaction. Faculty loads have been relieved through creative use of video tape and by having larger class size for the basic courses, thus permitting more faculty time for the projects. A unique feature of the program is the competency examination, which is a capstone examination wherein the students self-learning capability is examined.

WPI is expanding its efforts in the graduate program area with increased quality being the most important goal but also to include increases in enrollments. The Electrical Engineering Department hopes to double the enrollment in their graduate program over the next 5 years. Industry has provided excellent support, particularly with manufacturing engineering equipment. There is, however, a continuing need for updating equipment. Outside research brings in approximately $2,000,000 with an additional $2,000,000 of research in hydraulic modeling being done at the separate Alden Research Laboratory. A 35,000 square foot wing is to be added to the EE building to provide an approximate 50% expansion for the Electrical Engineering and Computer Science Programs.

Appendix C

Reports - Community Colleges

REPORT ON
COMMUNITY COLLEGES IN MASSACHUSETTS
OFFERING ENGINEERING TRANSFER PROGRAMS

MARCH 11-14, 1984

by

RICHARD J. UNGRODT

OBJECTIVES OF THE VISIT

1. To review the status of the pre-engineering transfer programs.
2. To review the relations which have been established between the Community Colleges and the Senior Colleges, particularly the articulation agreements and/or the arrangements for transfer of students.
3. To discuss the relative strengths and weaknesses of the pre-engineering transfer programs.
4. To provide suggestions and/or recommendations for improvement.

INSTITUTIONS AND PERSONS VISITED

Berkshire Community College - March 12, 1984

Donald Herdman, Dean of Academic Affairs
Daniel Minneci, Chairman, Sciences and Engineering Division
Edwin Clark, Chairman, Engineering and Technology Department

Bristol Community College - March 13, 1984

Al Roy, Academic Dean
Charles Blank, Assistant Academic Dean
Philip Gover, Chairperson, Division of Business and Engineering
David Warr, Chairperson, Division of Math and Science
Fred Hanack, Program Director, Engineering
John Capone, Associate Professor, M.E. Department
John Majcut, Associate Professor, E.E. Department

Cape Cod Community College - March 13, 1984

William Young, Academic Dean
Bruce Bell, Chairperson, Div. of Math, Science, Engineering & Related Technolog
Ted Panitz, Engineering Program Coordinator

Greenfield Community College - March 12, 1984

Theodore Provo, President
Toby Sutton, Dean of Academic Affairs
Carleton Stinchfield, Chairperson, Natural Science Division
Lee Webster, Faculty, Civil Engineering Department

Holyoke Community College - March 12, 1984

Philip Campbell, Dean of the College
Gerard L'Heureux, Chairman, Div. of Math, Physical Sciences and Technology
John Sokol, Program Coordinator for Engineering
David Sussman, Program Coordinator for Electromechanical Technology

North Shore Community College - March 13, 1984

Paul Frydrych, Dean of Academic Affairs
Neil Shea, Director, Engineering Science Program
Bert Von Blumenkrantz, Chairman, Div. of Science and Math

Northern Essex Community College - March 13, 1984

Robert McDonald, Dean of Academic Affairs
Corinne Grise, Chairperson, Div. of Math, Science and Technology
Michael Pelletier, Coordinator, Academic Computing
Robert Sacchetti, Coordinator, Engineering and Science Program

Quinsigamond Community College - March 14, 1984

Bob Bowden, Acting Academic Dean (& Chairman, Div. of Social Sciences)
Dick Baldwin, Chairman, Div. Math, Science and Technology

Springfield Technical Community College - March 12, 1984

John Dunn, Dean
Jack Varocas, Chairman, Div. Math, Science and Engineering
William White, Chairman, Engineering & Science Transfer Department
Juris Zagarins, Assistant Professor, Materials Science
Robert Geitz, Professor, Chem. E. Department
Tony Sylvestri, Associate Professor, Computer Science

Wentworth Technical Institute - March 14, 1982

Ted Kirkpatrick, President
Arthur Thompson, Provost

GENERAL OBSERVATIONS

Objectives: The comprehensive objectives of the community colleges which were reviewed are quite similar. They provide upward academic mobility for local students through various educational opportunities including remediating students' academic deficiencies.

They all provide students with the opportunity to obtain entry into the first two years of a collegiate program of studies with the objective of transferring to a university for a professional program. They also provide two-year terminal programs for careers in para-professional areas.

The pre-engineering, or engineering transfer programs, provide a unique service for the graduates who who can transfer to an upper division institution with approximately two years of credit. Enrollment statistics indicate a fair number of students enrolling in the pre-engineering program. However, there is a relatively low number of graduates who complete the two year program. This fact indicates there are many students who attend the community college for a relatively short period of time in order to remove specific deficiencies in mathematics or sciences. When these deficiencies have been removed, many students feel ready to transfer directly to an upper division institution and do so without completing any further work at the community college. In this respect, the objective of providing upward academic mobility for local students is met.

Students

The student enrollments in the Engineering Transfer Programs at the various community colleges seem to have reached a stable level.

The students were reported as being more mature, highly motivated and interested in furthering their academic knowledge. The academic quality of the student body was reported as being lower than that found at the university in similar engineering programs. However, the students in general have been academically disadvantaged during their high school period either for lack of personal motivation or for lack of the required math and science subjects in the high school. In a number of cases students were dropouts from college who have now matured and have increased motivation and interest for further academic work.

The attrition in the first year of the pre-engineering programs is exceedingly high. This program, however, does permit students to explore the engineering area to decide if they are interested in further engineering studies. Many students find this a convenien way of transferring to other technical programs within the community college.

It is obvious that there will always be a fair number of students with varied backgrounds who will utilize the services of the community colleges for entry into the upper division engineering program of a senior college.

The resource of technical manpower which can be provided for the State of Massachusetts will thus be increased.

Faculty

Faculty are consistently dedicated and loyal to the community colleges. In general, their academic and theoretical background is satisfactory for the level of work they are presenting. Their emphasis and interests are in teaching their students and in helping them to overcome any deficiencies in knowledge or abilities which prevent them from advancing to the senior college.

Faculty generally do not have engineering backgrounds and thus are seriously limited in presenting the technical subjects often desired by the senior college in the second or sophomore year. The faculty workloads under the current union contract appear to be acceptable to most of the faculty. Faculty stability appears to be good with a rather limited turnover. There is some concern, however, that this very low turnover may indicate that some stagnation is occurring. This is particularly critical, since there are seriously limited opportunities for professional development activities available to faculty members. With the rapid changes in technology and the advancement in technical areas, this is a matter of serious concern.

A major effort must be made to improve the opportunities for the professional development of the faculty members by providing additional financial support for travel, for participation in seminars, and particularly for activity in technical societies, not only in the immediate community, but for occasional meetings at the national level.

The competition for new faculty qualified in the engineering and computers areas is becoming much more critical than it has in the past. The current marketplace in industry can provide a much higher salary level than the average college faculty member receiv Although this problem is not unique to community colleges, it is much more aggravated in view of the current exceedingly low salaries for the community college faculty. The union contract which does not allow for merit or marketplace considerations can be a serious hindrance to developing the qualified faculty necessa to provide a quality program in the engineering transfer area.

Recognizing the unique requirements for engineering faculty as well as for specialized technical laboratories, it would therefore be expedient to limit the engineering transfer program to a very few selected community colleges.

Curriculum-Model Transfer Program

The model transfer program that is currently being discussed should be implemented as soon as possible at a few selected institutions. The articulation agreements which have currently been established do provide a reasonable transfer opportunity for most students. Difficulties exist as a result of differences in curric at the upper division public institutions, since they themselves have not yet agreed upon a common first two years for their engineering programs.

Since no common model engineering program exists at the public universities, any model transfer curriculum cannot match the curricula at all of the public universities.

The articulation agreements which have already been established between specific universities and the community colleges are apparently working out quite well and should be further explored and expanded where appropriate. Since the public universities do not themselves agree on a common first two years, it will be important that advertising by the community colleges is clear in identifying the situation; i. e. that their transfer program cannot meet the requirements of all of the institutions, both public and private in the state of Massachussetts.

The various community colleges might best monitor their transfer programs so as to meet the interests of the institution to which most of their students transfer. Students who do complete the engineering transfer programs are generally quite successful in the engineering programs at the institutions of higher education.

Facilities:

The academic facilities of the community colleges are generally adequate. There are a number of institutions, however, with a serious deficiency in space — primarily related to laboratory equipment, laboratory maintenance and capital improvement. Computer facilities are generally not at the level they should be and will require exceedingly careful monitoring in order that the students are ready to transfer to the upper division programs. The fact that different computer languages are being utilized at the various institutions is a subject of serious concern which must be addressed.

In a number of cases, the engineering transfer program on the campus actually enhanced and supported other academic programs, particularly in connection with the physics and chemistry laborator

Institutions with low enrollments in the engineering transfer program might best consider offering a very basic program of core subjects and exclude any of the special technical subjects required in the various engineering areas in the sophomore year. The limited laboratory facilities and the lack of engineering faculty dictate that only a basic transfer program be offered at most of the institutions.

Administrative Support:

The engineering transfer program appears to have full support of the administration at all levels within each of the community colleges reviewed. Excellent cooperation exists between the community colleges and the senior colleges in the geographic area. In particular, the Deans of Engineering have established programs to bring together the community college personnel to discuss the model transfer programs. Curriculum changes are brought to their attention at that time.

SUGGESTIONS AND RECOMMENDATIONS

The extensive nature of higher education in Massachusetts is most noteworthy. The system encompasses a broad spectrum including public and private colleges and universities, and community colleges and technical schools. Any recommendations to expand or contract to approve or to limit expansion of curricular offerings will produce strong reactions from the various constituent groups.

In order to provide academic opportunities for more citizens and to improve the quality and quantity of the technical workforce, a strengthening of a few community college engineering transfer programs would be justified. Just how this is to be accomplished will depend to a great extent on the commitment of funds and development efforts to be assigned to the community colleges and/or to the engineering colleges. Complete cooperation of all groups will be necessary.

Key areas of concern will include:

I. A substantial increase in funding for laboratory and computer equipment and faculty development at a few selected institutions.

II. Selection of a few key "specialty" community colleges to offer selected engineering subjects for the engineering transfer program. Other community colleges should concentrate on remediation in upgrading student skills in math and sciences and in offering basic core subjects for engineering tran students without a full complement of sophomore engineering subjects.

III. Regular two-way communications must be developed to include the engineering colleges and related community colleges. This formal process should also include meetings of department and division heads for one-on-one dialogue of common problems and concerns existing at the community college and engineering colleges. One other organization of community college department or division heads might be desirable with regular state-wide meetings to discuss, evaluate and propose solutions to common problems.

IV. The current institutions offering four-year engineering programs can fill the need for qualified engineering graduates in Massachusetts. No other institutions should be authorized to enter the engineering education field at this time.

FACULTY

1. Professional development of current faculty must be improved. Additional funds and formal programs for providing individuals with challenging and stimulating activities are necessary. The rapid changes in technology and in computer utilization and languages will soon make a stable faculty obsolete unless they are involved in a personal program of professional development. Additional funds will be required to support professional and technical society activities and memberships and partipation at local, regional and national meetings.
2. Each institution should identify the unique strengths and weaknesses of each of the technical faculty as it relates to their academic offerings and mutually develop individual programs of professional development for each. The responsibilities of the individual faculty member as well as the community college should be agreed upon.
3. A system-wide plan should be established for each curricular area which could utilize continuing education programs developed by the major technical-professional societies. The founder societies such as I.E.E.E., A.S.C.E., A.S.M.E. and others such as S.M.E. have all developed extensive

programs for remote presentation. Purchase by the state system for distribution and use at the community colleges would be a cost-effective means of providing current technical information.

4. Differential salary schedules will be needed to meet the market place competition for engineering and computer science faculty.
5. Faculty workloads are controlled by union agreements; however, additiona support personnel, lab technicians, etc. might effectively develop time for faculty to get involved in more professional activities.
6. Faculty consulting and closer industry relations should be encouraged with guidelines and controls to stimulate activity and to protect from abuses.
7. Appropriate continuing education programs, seminars and workshops offered by the public universities should be made available at little or no cost to the community college faculty.
8. A faculty exchange program for a semester or one year should be establishe to provide community college faculty supervised teaching experiences at the public universities in the specialty subjects of the sophomore year. University faculty could help develop the appropriate laboratories and related technical courses at the community college to improve the articulation of transfer students.

STUDENTS

9. Enrollment planning and control should be explored with all institutions. If the engineering colleges shift their resources and enrollment emphasis to the upper levels and to graduate programs, then improved articulation curriculum & transfer policies will be needed with the community colleges.

If the engineering colleges depend on the community colleges for a larger number of transfer students, then additional state support will be required for laboratory equipment and specialty faculty at the selected community colleges.

10. Academic advising programs must be strengthened to aid students in career guidance and for selection of their major engineering field of study.
11. Students should be carefully advised that to complete the engineering program will likely require more than four academic years, and that students who start with remedial subjects at the community colleges will generally take five or more years to complete.
12. Students should be carefully advised concerning the lack of uniformity of the first two years of engineering at the colleges and universities in Massachusetts, and therefore, there can be no exact match with the engineering transfer program and all engineering programs in the state.

FACILITIES

13. Computer facilities require upgrading at a number of institutions. Software requirements need to be established and languages correlated with the senior institutions who have not yet agreed upon one computer language.
14. A major funding effort will be required for those community colleges that are selected to offer sophomore engineering type courses with laboratories. Both capital equipment funds as well as annual maintenance funds will be needed.

CURRICULUM AND ARTICULATION AGREEMENTS

Since there is no common model engineering program adopted by the public universities, there can be no match with the model transfer program which is currently under consideration. Therefore, the following recommendations are submitted for consideration:

15. Each community college should critically review its resources and consider offering only those basic core subjects which do not require additional specialty (engineering type) faculty, and costly laboratory equipment and space.

16. Certain community colleges should be designated as "specialty" schools to offer selected engineering type subjects which relate to other curricular offerings and laboratory facilities currently in place, or to meet the specific needs of its geographic service area and the Engineering College to which a majority of its students transfer. Articulation agreements must then be developed with that primary college of engineering.

Springfield Technical Community College and Northern Essex Community College should be designated as "specialty" schools with engineering transfer programs. North Shore Community College has a good future potential for becoming a specialty school, however, the program should be offered at either the Lynn or Beverly Campus but not at both. The economic and industrial growth in the geographic area of Bristol Community College should be monitored with the possibility that some time in the future Bristol might also be designated a specialty school.

17. Transfer articulation agreements should be developed individually between the community college and the engineering college receiving the majority of these students and should include communications at the division and department level.

18. The dynamic nature of engineering curricula will require continuous revisions in the curricula at the community colleges. As the engineering colleges develop more project-type courses and move them and other engineering problem solving courses into the sophomore or freshman level, the specialty community colleges will be faced with a completely new dimension in their specialty classes with a costly expansion of laboratory equipment and engineering facul

19. The development and utilization of various computer languages by the colleges of engineering requires closer coordination with the related community colleges. As both hardware and software develop, this problem will likely be aggravated.

BERKSHIRE COMMUNITY COLLEGE

Berkshire Community College is a relatively small college with no "corridors of specialty." In philosophy, they might be considered as generalists offering twenty programs in four divisions. Enrollment is approximately 2,000 in the day and approximately 1,300 in the evening.

Graduates from the local high schools do not provide the primary source of students, since unemployment in the area brings career changes and enrollment. Approximately 50% of the students enrolling transfer to a wide range of institutions of higher education including the University of Massachusetts.

A large number of college students transfer to Berkshire for their academic studies. Ninety percent of the engineering transfer students generally complete two years, however, it was indicated that students do not leave until they are ready for the upper division institution.

Formal articulation agreements do not exist at the present time, however, an agreement is being developed with the University of Massachusetts. Meetings have been held with both public and private institutions in the region to discuss informal transfer arrangements for Berkshire students. Seventeen regional high schools are regularly visited, thus providing some degree of articulation at that level.

BRISTOL COMMUNITY COLLEGE

Bristol Community College is situated in southeastern Massachusetts, serving a large population including a large number of first-generation immigrants. There is concern for upward mobility on the part of the young people. The area has the historically lowest rate of high school graduates and the lowest family income, as well as linguistic problems. The area has had the highest unemployment for a forty-year period of depression, developing a down-cycle attitude on the part of the parents and little support for high school achievers. The area is supported in part by diversified light manufacturing, including apparel, electronics, lighting and rubber industries. Software computer activities are now developing.

Enrollment includes 2664 day students and 2450 part-time evening students. Programs are offered in six divisions. There are 90 full-time faculty and 70 part-time faculty. There are 7 full-time faculty and 2 part-time faculty in the Engineering Department. The evening division utilized 200 to 300 "adjunct" faculty.

The engineering transfer program is stable at approximately 120 in addition to 60 pre-engineering students. The survival rate of 62% was reported for the two-year program.

Students enrolled in the transfer program are academically fairly good, but often need upgrading before enrolling in the mathematics and science courses required in the program. Approximately one-third come from the regional vocational high schools. The institution desires stronger articulation arrangements with the four regional vocational high schools.

Articulation agreements have been established formally with Roger Williams College and with SMU. Confusion exists as to how the model curriculum might be implemented because the public engineering colleges lack a common curriculum at the lower division level.

CAPE COD COMMUNITY COLLEGE

Cape Cod Community College is unique in its extensive summer activity due to the geographic location where vacationing students usually enroll. An enrollment of 1,600 day students and 1,650 evening students was reported. Enrollment in the engineering transfer program includes 50 students including the preparatory program. Approximately 20 students advance to the freshman level and ten to fifteen enroll in the sophomore level. Student population is unique in a bi-polarization nature with more students entering with poor preparation in mathematics, while there is also an increase in the number of better-prepared students from the middle-class economic sector. It was also noted that more women were enrolling. Approximately one-half of the graduates transferred to the University of Massachusetts and the other half to Southeastern Massachusetts University.

Cape Cod Community College has found an innovative means of supporting faculty development through a special "fund for retraining and new technical developments." This provides limited support.

Articulation agreements are being developed with the University of Massachusetts but serious concern was evidenced for the one-way model whereby the community colleges have little opportunity to address their concerns to the upper division institution.

GREENFIELD COMMUNITY COLLEGE

Greenfield Community College has been established for 20 years in a rural location but reasonably close to the University of Massachusetts. It is close to the industrial community and therefore has strong programs in the electronics areas.

With 1,625 day students and 1,750 evening students, it is probably one of the smaller community colleges in the state. Enrollments in the engineering transfer program are relatively low, with 32 in the pre-engineering and first year and 19 at the sophomore level. Another 20 evening students are in the transfer program.

The Greenfield Community College Foundation is 18 years old with 250 members who have provided an endowment of one-half million dollars. From $50,000 to $60,000 per year is available for use by the institution. Professional development funds are provided in the amount of $5,000 per year for the total institution. The regular budget supplies only $50 per year per faculty member.

It is reported that 80% of the students transfer to the University of Massachusetts. Registration is unique in that students are in liberal arts with a concentration in engineering transfer subjects.

Some of the current facilities are ten years old and are depending upon original equipment which needs to be upgraded. Plans for a new building are in the initial phase. Completion of that building may free up space for the engineering program in an existing facility.

Articulation agreements are being developed with the University of Massachusetts. A few students transfer to the University of Lowell and Southeastern Massachusetts University, but encounter little difficulty.

HOLYOKE COMMUNITY COLLEGE

Holyoke Community College enrollment is 3,200 day, 2,200 evening with six divisions. The engineering transfer program is in the Division of Physical Sciences, Mathematics and Technology. The division enrolls 400 students.

Enrollment in the engineering transfer program is approximately 120, including the pre-engineering. Sophomore enrollment is approximately 30, with only 10 completing requirements for graduation. Most students transfer prior to completing the two-year transfer program, or they move to the engineering technology program, which is separate and distinct from the engineering transfer program.

Articulation agreements are in the process of being developed with the University of Massachusetts for programs in Electrical and Mechanical Engineering. Sixty to seventy percent of the students transfer to the University of Massachusetts.

NORTH SHORE COMMUNITY COLLEGE

North Shore Community College is situated 28 miles north of Boston, serving the north shore of Boston. It is unique in having two facilities approximately 11 miles apart. Current enrollment is 2,900 day division students and 5,000 students in the Division of Continuing Education.

New facilities will be available in Lynn in the spring of 1985, supplementing the facilities in Beverly and the Norwood Pond Campus now in the planning stage. Eventual plans would include two campuses at Lynn and Beverly, 11 miles apart.

The area has a high unemployment rate. In the past, this was a dynamic industrial community. The pool of students includes two sectors - economically poor families as well as students from middle-class families who could afford to send their children to the university. The 450,000 people in the primary service area, therefore, provide students with a strong interest in the community college. The engineering transfer program is anticipated to double with the completion of the two campuses.

Articulation agreements have been established with a number of institutions e.g. Salem State and the University of Lowell where formal agreements have been developed with the program coordinator for the Mechanical Engineering program. Students have access to the Northeast Consortium of Colleges and Universities in Massachusetts and the cross-registration policy without additional tuition.

The Center for Professional and Academic Development provides a unique program available to the faculty, staff and administration to bring speakers and to develop other means of supporting professional development. A Professional Day is regularly scheduled, with workshops, speakers and seminars as an all-college activity.

NORTHERN ESSEX COMMUNITY COLLEGE

Northern Essex Community College is a comprehensive institution with 3,600 day students and 5,000 evening students. There are six academic divisions. In addition, there are 75 students at two industrial locations. More Hispanics are moving into the area and therefore, to the engineering transfer program. An increase in female population has also been noted. Growth is anticipated in the engineering transfer program when the University of Lowell limits their enrollments, thus encouraging the community college to do the "weeding" in the first two years.

Facilities are overloaded; scheduling of large laboratory and lecture classes has produced difficulties in maintaining quality education. Special budget action this year provided $50,000 to supply some computer equipment; however more is required.

Articulation agreements are in the process of being developed with the University of Lowell; however, there is concern that the model curriculum does not meet both curricula at the University of Massachusetts and the University of Lowell.

There was evidence of concern about the polarization within the faculty betwee the technical and the non-technical faculty with respect to salary, benefits, workloads, etc.

The size of the program is large enough to have several faculty with engineering degrees and some industrial experience. A large number of students complete their program and enter the University of Lowell engineering program.

QUINSIGAMOND COMMUNITY COLLEGE

Quinsigamond Community College serves an area which was previously heavy industry and manufacturing that is now moving toward high technology. Therefore, the college is heavily involved in retraining for high technology.

Student population was reported at 2,600 day students and 3,000 evening students and is anticipated to be fairly stable in enrollment. The current limitations on space throughout the campus is a factor influencing difficulty in offering appropriate laboratory classes in the division. Plans are in process for a new building.

It is particularly noted that the four semester physics sequence is offered without calculus until the fourth semester, although a little calculus is included in the third semester. The University of Lowell requires a calculus-based physics, therefore transfer students must repeat the physics sequence. The University of Massachusetts generally accepts the physics as a four semester package.

The institution serves three universities as well as a number of private institutions. Since there is no model engineering program adopted by the public universities, there can be no match with the model transfer program which is currently under consideration.

SPRINGFIELD TECHNICAL COMMUNITY COLLEGE

Springfield Technical Community College is unique in its origin, offering strong technical and engineering technology programs over a long period of time. It is the only school in the Springfield area offering the pre-engineering/engineering transfer program. The program is separate from the engineering technology curriculum which is a non-calculus-based curriculum. Currently enrollment includes 3,600 day school and 3,600 evening students in nine divisions. A trend toward a younger student population was noted.

Articulation agreements are not currently established. The institution, however, customizes the student's sophomore schedule for easy transfer to the Worcester Polytechnical Institute or the University of Massachusetts.

Computer facilities are located in the business school, which controls its use. The engineering transfer students, therefore, have limited access to the equipment. A decision on the utilization of the computer either on a closed or open system is necessary at Springfield.

In addition to the pre-engineering students, 129 students were enrolled in the engineering transfer program. Students were very well qualified in terms of pre-college test scores and acceptance by the engineering schools of the State. The faculty were qualified by virtue of academic engineering degrees and experience in industry.

Appendix D

Massachusetts Statistics

TABLE D-1

ENGINEERING PROGRAMS BY LEVEL

	Umass Amherst	SMU	Univ Lowell	Mass Mari	B.U.	Harvard	MIT	Merrimack	Northeastern	Tufts	Western N.E.	W.P.I.	Total
erospace					B,M		B,M						2
Biomedical					B,M,D						B,M	M,D	3
Chemical	B,M,D		B,M				B,M,D			B,M,D		B,M,D	6
Civil	B,M,D	B	B,M				B,M,D	B	B,M	B,M		B,M,D	8
Ceramics							M						1
Computer	B	B	B		B,M		B,M,D				B		6
Construction		B											1
Environmental	M,D										B		2
Engineering Design										B,M,D			1
Engineering Mgt.	M								M		B,M		3
Engineering Sci.						B,M				B	B		3
Energy			M										1
Electrical	B,M,D	B,M	B,M		B,M,D		B,M,D	B	B,M,D	B,M,D	B,M	B,M,D	10
Fire Protection												M	1
Industrial	B,M,D								B,M		B		3
Marine				B									1
Manufacturing	M				B,M,D								2
Metallurgical							M						1
Materials Science							B,M,D						1
Mechanical	B,M,D	B	B,M		B,M,D		B,M,D		B,M,D	B,M,D	B	B,M,D	9
Naval Architecture							B,M						1
Nuclear			B				B,M,D						2
Ocean	M,D						B,M,D						2
Paper			B										1
Plastics			B,M										1
Polymerics							M						1
Systems			M		B,M,D								2
Textiles							M						1

B = Baccalaureate
M = Masters
D = Doctorate

TABLE D-2

ENGINEERING TECHNOLOGY PROGRAMS
BACCALAUREATE LEVEL

	Univ. Lowell	Southeastern Mass Univ.	Central New England	Suffolk	Wentworth
Architectural					x
Building Const.					x
Civil	x		x		x
Computer Info			x	x	x
Computer Science			x	x	x
Electronic	x	x			x
Electrical			x		
Industrial/Mech.	x		x		
Manufacturing					x
Management Tech			x		
Mechanical	x	x			x
Technical Mgt.					x

TABLE D-3

UNDERGRADUATE AND GRADUATE ENROLLMENTS

	1977-78		1978-79		1979-80		1980-81		1981-82		1982-83	
	U	G	U	G	U	G	U	G	U	G	U	G
UMass-Amherst	1694	241	1925	231	2037	247	2183	303	2326	318	2246	252
Univ of Lowell Day	2115	526	2066	722	2122	379	2492	433	2593	472	3013	626
Evening	885	509	1045	375	1094	506	1055	921	1378	451	995	537
Southeastern Mass Univ	759	10	780	6	786	12	835	11	942	17	989	15
Mass Maritime[1]	643	0	687	0	674	0	668	0	647	0	615	0
Total - Public	6096	1286	6503	1334	6713	1144	7233	1668	7886	1258	7858	1430
Boston University	672	60	896	75	1077	99	1314	120	1488	169	1629	181
Harvard University	12	0	5	0	0	0	4	0	12	0	0	0
Mass Inst of Technology	2635	2001	2827	2048	2945	1985	3035	1855	3165	1853	3189	1799
Merrimack College	154	0	161	0	178	0	176	0	192	0	227	0
Northeastern University	2806	397	3391	425	3972	480	4449	505	4500	559	4154	591
Tufts University	878	144	877	135	884	146	930	139	976	114	929	141
Western New England	462	23	554	40	594	40	592	54	609	60	698	63
Worcester Polytechnic	1600	225	1610	235	1621	193	1686	184	1785	201	1750	290
Total - Independent	7619	2850	10321	2958	11271	2943	12186	2857	12727	2956	12576	3065

Table D-4
Undergraduate & Graduate Degrees

	1977-78			1978-79			1979-80			1980-81			1981-82			1982-83		
	Bacc	Mast	Doct	Bacc	Mast	Doct	Bacc	Mast	Doct	Bacc	Mast	Doct	Bacc	Mast	Doct	Bacc	Mast	Doct
Mass. Maritime	122	0	0	123	0	0	122	0	0	150	0	0	127	0	0	112	0	0
University of Lowell[1]	338	44	0	335	49	0	326	68	0	311	97	0	440	91	0	500	94	0
UMass - Amherst	301	83	24	280	67	25	320	73	11	321	70	9	383	91	17	447	89	26
Southeastern Mass[1]	108	6	0	146	7	0	151	8	0	133	10	0	154	7	0	199	6	0
TOTAL PUBLIC	869	133	24	884	123	25	919	149	11	915	177	0	1104	109	17	1447	189	26
Boston University	65	20	0	99	35	0	125	55	0	167	52	0	204	53	0	229	73	0
Central New England[2]	40	0	0	43	0	0	43	0	0	79	0	0	71	0	0	123	0	0
Harvard University	6	0	0	1	0	0	1	0	0	2	0	0	4	0	0	0	0	0
Mass. Inst. of Tech.	552	517	177	698	515	144	666	559	162	683	574	162	721	632	169	742	602	171
Merrimack College	22	0	0	23	0	0	32	0	0	41	0	0	39	0	0	34	0	0
Northeastern Univ.	344	117	2	480	111	3	514	113	1	580	108	4	597	119	1	604	256	2
Tufts University	126	28	1	134	49	0	151	29	1	199	54	2	183	31	2	174	50	3
Wentworth Inst. Tech.[2]	127	0	0	104	0	0	121	0	0	154	0	0	140	0	0	257	0	0
Western New England	58	2	0	42	14	0	71	13	0	62	11	0	73	22	0	73	17	0
Worcester Polytechnic	300	50	2	313	47	3	395	57	1	340	51	4	390	56	0	404	64	3
TOTAL INDEPENDENT	1640	734	182	1937	762	150	2119	826	165	2307	850	172	2422	913	172	2640	826	179

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[1] Includes Engineering Technology

[2] Engineering Technology Programs

TABLE D-5

ENGINEERING DEGREES CONFERRED

MASSACHUSETTS PUBLIC INSTITUTIONS

BACHELORS

ACADEMIC YEAR

PROGRAM	NO.*	77-78	78-79	79-80	80-81	81-82	82-83	TOTAL*
Chemical	2	72	100	80	61	108	88	509
Civil	3	164	124	148	123	115	137	811
Computer	2	0	14	20	9	30	17	90
Electrical	3	173	156	191	186	207	334	1239
Industrial	2	71	88	72	72	97	140	540
Marine	1	122	123	122	150	127	112	756
Mechanical	3	157	143	184	202	243	261	1192
Nuclear/Energy	1	22	24	12	14	8	13	93
Construction	1	0	0	0	0	1	3	4
Plastics	1	27	27	42	44	53	41	236
Total		810	831	871	863	891	1166	5532

MASTERS

PROGRAM	NO.*	77-78	78-79	79-80	80-81	81-82	82-83	TOTAL*
Chemical	2	15	5	8	13	10	14	66
Civil	2	13	21	11	16	12	20	95
Computer	1	29	26	44	58	30	38	235
Electrical	3	48	19	36	44	47	58	272
Environmental	2	11	3	11	12	15	10	63
Industrial	1	7	6	5	11	12	5	46
Manufacturing	1	0	0	9	0	8	6	23
Mechanical	2	20	22	33	27	25	19	147
Nuclear/Energy	1	5	0	1	3	4	3	13
Ocean	2	0	3	1	2	0	0	6
Paper	1	0	0	1	2	2	6	11
Plastics	1	10	9	12	3	17	22	73
Systems	1	0	2	6	10	3	5	23
Total		151	138	178	213	139	206	1390

DOCTORATE

PROGRAM	NO.*	77-78	78-79	79-80	80-81	81-82	82-83	TOTAL*
Chemical	1	5	7	2	1	4	11	30
Civil	1	2	1	3	1	4	5	16
Electrical	1	7	5	2	4	3	4	25
Environmental	1	1	1	2	1	0	0	5
Industrial	1	5	6	0	2	5	5	23
Mechanical	1	3	3	1	0	1	1	9
Ocean	1	0	2	1	0	0	0	3
Total		23	25	11	9	17	26	111

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*Total number of institutions offering program in 1982-83

Table D-6 (con't)

Civil

	1977-78			1978-79			1979-80			1980-81			1981-82			1982-83		
	Bacc	Mas	Doc	Bacc	Mas	Doc	Bacc	Mas	Doc	Bacc	Mas	Doc	Bacc	Mas	Doc	Bacc	Mas	Doc
Univ. of Lowell	65	2	0	35	6	0	54	3	0	31	8	0	39	7	0	45	3	0
UMass-Amherst	301	83	24	280	67	25	320	73	11	321	70	9	383	91	17	477	89	26
Southeastern Massachusetts	22	0	0	21	0	0	25	0	0	32	0	0	25	0	0	20	0	0
M.I.T.	62	76	24	68	82	14	61	94	17	44	76	22	40	77	19	35	65	18
Worcester Tech	58	11	0	64	11	0	61	13	0	54	14	0	60	12	0	55	7	0
Northeastern	104	36	0	139	45	1	156	38	0	161	35	0	145	32	0	141	52	0
Merrimack	18	0	0	17	0	0	23	0	0	28	0	0	16	0	0	22	0	0
Tufts Univ.	36	14	0	28	21	0	31	12	0	43	20	0	30	18	0	32	29	0

Chemical

Lowell	29	5	0	49	2	0	36	1	0	18	1	0	47	2	0	36	3	0
UMass-Amherst	301	83	24	280	67	25	320	73	11	321	70	9	383	91	17	477	89	26
M.I.T.	92	69	15	108	67	8	115	63	15	117	61	15	117	56	17	101	69	18
Worcester Tech				41	3	2	81	11	1	39	9	1	54	10	0	48	7	2
Northeastern	15	5	5	42	5	1	36	10	1	46	6	0	38	11	0	35		
	28	5	0	34	2	0	41	8	0	38	11	2	32	3	0	37	4	1

Table D-6 (con't)

Mechanical

	1977-78			1978-79			1979-80			1980-81			1981-82			1982-83		
	Bacc	Mas	Doc	Bacc	Mas	Doc	Bacc	Mas	Doc	Bacc	Mas	Doc	Bacc	Mas	Doc	Bacc	Mas	Doc
Univ. of Lowell	84	3	0	89	9	0	68	10	0	70	3	0	68	1	0	69	2	0
UMass-Amherst	72	18	3	56	21	3	85	30	1	111	17	0	130	17	1	147	16	1
Southeastern Mass	16	0	0	21	0	0	29	0	0	23	0	0	24	0	0	30	0	0
Western New England	18	0	0	18	0	0	35	0	0	35	0	0	35	0	0	27	0	0
Boston Univ.	13	1	0	20	1	0	21	4	0	20	5	0	31	4	0	40	5	0
M.I.T.	96	78	20	152	77	24	122	96	21	142	114	19	120	116	24	130	133	27
Worcester Tech		16	0	116	9	0	138	12	0	132	9	0	146	12	0	170	12	0
Northeastern	62	15	1	81	14	0	107	15	0	130	16	1	146	20	0	29	0	0
Tufts Univ.	38	3	0	38	6	0	30	5	1	70	9	0	72	6	0	56	7	2

Computer

	1977-78			1978-79			1979-80			1980-81			1981-82			1982-83		
	Bacc	Mas	Doc	Bacc	Mas	Doc	Bacc	Mas	Doc	Bacc	Mas	Doc	Bacc	Mas	Doc	Bacc	Mas	Doc
Univ. of Lowell	0	19	0	0	26	0	0	44	0	0	68	0	0	30	0	0	38	0
UMass-Amherst	0	10	0	14	0	0	20	0	0	9	0	0	23	0	0	Joined with Electrical		
Southeastern Mass	Not in Operation												4	0	0	7	0	0
Western New England	Not in Operation															2	0	0
Boston Univ.	19	9	0	7	15	0	14	17	0	26	14	0	35	26	0	36	29	0

Table D-7

Enrollment and Associate Degrees
Community Colleges

	1979-1980		1980-1981		1981-1982		1982-1983	
	# Majors	# Grads.	# Majors	# Grads.	# Majors	# Grads.	# Majors	# Grads.
Berkshire	41	10	41	3	83	11	109	13
Bristol	84	8	128	6	127	16	121	NA
Cape Cod	19	3	27	2	30	3	30	3
Greenfield	35	6	47	8	72	9	77	9 (est'd)
Holyoke	70	7	106	5	112	10	121	4
Northern Essex	104	21	82	23	132	44	132	29
North Shore	0	0	0	0	22	1	65	NA
Quinsigamond	102	15	90	11	62	14	77	NA
Springfield Tech.	82	18	112	32	121	37	129	25
U Mass-Boston	48	NA	76	NA	76	NA	103	NA

Table D-8
ENROLLMENT PROFILE BY SEX AND RACE
Community Colleges

	Year	Female	Male	White	Black	Hispanic	Asian	Other	Total
Berkshire	1980-81	3	73	75	1	0	0	0	76
	81-82	10	91	101	0	0	0	0	101
	82-83	18	102	119	1	0	0	0	120
Bristol	80-81	5	117	90	0	0	2	30	122
	81 - 82	12	114	119	0	1	0	6	126
	82-83	16	105	108	0	1	3	9	121
Cape Cod	80-81	4	23	27	0	0	0	0	27
	81-82	5	25	30	0	0	0	0	30
	82-83	6	24	30	0	0	0	0	30
Greenfield	80-81	5	41	41	1	0	0	0	46
	81-82	5	48	46	2	1	2	2	53
	82-83	7	49	54	0	0	0	1	56
Northern Essex	80-81	14	68	79	0	1	3	0	82
	81-82	24	108	128	0	1	3	0	132
	82-83	18	114	126	0	2	4	0	132
North Shore	80-81	4	11	NA	NA	NA	NA	NA	15
	81-82	3	13	16	0	0	0	0	16
	82-83	2	24	23	0	0	2	1	26
Quinsigamond	80-81	15	75	69	0	3	2	16	90
	81-82	6	56	47	0	4	3	8	62
	82-83	2	32	27	2	1	1	3	34
Springfield Tech	80-81	11	100	100	2	1	0	8	111
	81-82	15	106	111	2	1	1	6	121
	82-83	16	113	114	2	2	1	10	129

Table D-9

SIZE OF ENGINEERING PROGRAM - FACULTY, STAFF AND STUDENTS (FTE)

FOUR YEAR INSTITUTIONS - 1982-83

	Admin. Staff	Teaching Faculty	Non-teaching Professionals	Secretarial/ Bookkeeping	Technicians	Grad. T.A.'s	Grad. R.A.'s	Grad. Students	Undergraduate Students
M.I.T.	56	373	226	279	51	246	883	2106	2436
Wentworth Inst.[1]	25	169	35	57	36	0	0	0	3440
Northeastern	13	138	10	20	15	27	1	591	4154
UMass-Amherst		114	8	25	11	58	0	362	1143
Univ. of Lowell	1	102	0	15	12	38	6	423	3052
Worcester Tech	2	82	4	9	11	40	26	193	1950
Boston Univ	0	63	0	6	2	3	2	157	1327
S.M.U.[1]	1	38	0	3	3	5	2	21	592
Harvard[2]	15	38	53	37	37	0	0	135	150
Western New England	3	25	0	3	3	2	0	41	611
Mass Maritime	3	20	3	9	1	0	0	0	615
Merrimack	1	10	0	2	2	0	0	0	227
Suffolk[1]	3	5	3	1	0	0	0	0	7
Tufts	5	38.5	3.5	9	5.5	12.5	7.5	106.5	924

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[1] All or part of this data is for Engineering Technology

[2] This data is for the entire Division of Applied Sciences

Research Expenditures for
Public and Private Institutions
by Source of Support

	Federal	State	Industrial	Other	Total
Public Institutions					
U Mass-Amherst	2,107,663	129,295	1,074,009	363,360	3,674,317
University of Lowell	992,000	0	150,000	0	1,142,000
SMU	196,899	0	35,000	0	231,899
Private Institutions					
BU	477,000	0	8,000	52,000	537,000
MIT	162,871,957	1,076,885	19,753,199	13,195,865	196,897,906 *
Northeastern	1,901,286	0	26,606	24,070	1,951,962
Tufts	267,000	0	111,000	99,000	477,000
Western New England College	0	0	0	17,000	17,000
Worcester Polytechnic	1,372,000	102,000	2,591,000	198,000	4,263,000

* Includes funds for various interdisciplinary centers (for example, transportation studies, plasma fusion, nuclear science, cancer center) and science programs in biology, chemistry, and physics.

Table D-11

Separately Budgeted
Research Expenditures

	Electrical/Computer	Mechanical	Chemical	Civil	Other	Total
Public Institutions						
U Mass-Amherst	1,190,679	659,582	673,838	509,968	640,250	3,674,317
University of Lowell	672,000	63,000	19,000	28,000	360,000*	1,142,000
SMU	231,899	0	0	0	0	231,899
Private Institutions						
BU	132,000	153,000	0	0	202,000	537.000
MIT	3,021,534	5,822,507*	2,279,885	3,778,884	38,689,475	53,592,285
Northeastern	1,887,757	50,401	282,000	31,447	82,073	2,057,960
Tufts	207,000	48,000	169,000	53,000	0	477,000
Western New England College	12,000	5,000	0	0	0	17,000
Worcester Polytechnic	249,000	286,000	686,000	50,000	2,992,000	4,263,000
		* Includes aerospace			* Includes 237,000 for plastics	

Appendix E

Regents' Statement on Manpower

STATEMENT ON ENGINEERING MANPOWER

From the

Ad Hoc Committee on Engineering Manpower

Once the Regents had decided to review engineering statewide, an essential component and logical first step was to forecast the need for engineering manpower for the remainder of the decade. To do this properly, it was important to understand the relationship between supply and demand. This was critical in determining whether the need for engineers was being met within the state. An analysis was carried out by Dr. Neville Lee, Senior Economist at the Bank of Boston. In order to place this analysis in perspective, the Ad Hoc Committee on Engineering Manpower reviewed the reports of projected demand for engineers of the Massachusetts High Technology Council, the Division of Employment Security, the National Science Foundation, and the American Electronics Association. The methodology employed in each study was explained to the Committee by key researchers involved in each of the studies. Various study components were examined and discussed to determine whether assumptions made in each were comparable or not, and if they were not, to understand why. In addition, the report of the Center for Labor Market Studies at Northeastern University and the American Electronics Association projections for Massachusetts were made available to the Committee.

The weight of the evidence compiled and examined indicates that the projected demand for entry level mechanical and chemical engineers is presently and will continue to be met by the projected supply of graduates and, in fact, in these fields there appears that there will be a surplus of engineers by 1987.

In electrical engineering, the situation is less clear regarding the balance between supply and demand. The studies cited above indicate that the demand for entry level electrical engineers per year will be matched by the numbers of graduates projected regardless of the methodology employed. Even with the sophisticated supply model developed for NSF by Robert Dauffenbach et al (which factors in items which influence supply such as numbers of new entrants available, immigrant entrance, outmobility and attrition) is applied, under various scenarios and assumptions, there appears to be at least a balance at the entry level. The rapid expansion of undergraduate engineering programs which has occurred in both public and private institutions is the major reason for the apparent balance between supply and demand.

It should be noted, however, in weighing the evidence and drawing conclusions that to date no methodology for projecting the balance between supply and demand for engineers has proven to be satisfactorily predictable. There continues to be wide differences of opinion between members of the high technology industry and the labor economists who try to assess the adequacy of future engineering manpower. Labor economists' models are based on historical data and do not take into account a possible shift in future hiring practices of high technology industries. If such companies were to shift their hiring practices and employ more new graduates instead of experienced engineers, there could be a shortage. In addition, further high tech industry growth may depend on such a shift actually occurring.

In view of these differences, the Ad Hoc Committee is recommending that a monitoring system be put in place, with a sense of urgency, to track data in the Commonwealth on supply and demand for engineers. This data should include the following information by engineering degree category: enrollment demand; degrees granted; position offers to graduates of both public and independent campuses; and engineering employment data, differentiated by degree category between entry level and experienced hires, from the major employers in the Commonwealth.

Since supply data from Massachusetts universities show that the number of baccalaureate engineering degrees granted after 1983-84 remains flat, it appears that capacity for undergraduate engineering education will not expand very much for at least the next two to three years. There was a consensus within the Committee that emphasis over the next few years should be placed on improving the quality of undergraduate engineering as opposed to further expansion of enrollments. This will give time to better assess the future needs for engineering educational capacity.

While engineering Baccalaureate and Master's degrees awarded are essentially doubling, the number of Doctorates awarded is decreasing by fifty percent. This decline poses serious problems for both engineering schools and industry. Doctorally educated engineers in greater numbers are essential to relieve high student/faculty ratios in our engineering schools, as well as to support growing research and development efforts in both universities and industry.

The consensus reached by the Ad Hoc Committee and its information were made available to the team of evaluators who began their site visits on February 5, 1984 and to the Deans of Engineering for their comments. The evaluation phase will attempt to focus on such questions as the improvement of program quality, whether programs are meeting current needs of industry, whether greater use of new instructional technologies should occur, and whether or not engineering schools should be more involved in retraining existing engineers.

At the completion of the evaluation phase, Dr. Joseph Hogan will develop a comprehensive report on engineering education in the Commonwealth with recommendations for Regents' consideration.